Production and Performance Analysis of Bio-Fuel Blends on a Diesel Engine

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Abstract: *Biodiesel is a cleaner burning diesel replacement fuel processed from natural renewable derived from biological sources such as waste cooking oil and refined bleached deodorized vegetable oil. The type of process that needs to be done to produce biodiesel is called "Transesterification". In the present study, the transesterification process has been done to obtain the biodiesel from three different vegetable oils (soya bean oil, palm oil and rice bran oil) and the performance of three such biodiesel fuels blended with Diesel in different composition has been investigated on single cylinder diesel engine.*

This study is also includes the performance comparison among the blended fuel and the conventional fuel (diesel alone) on the same single cylinder diesel engine based on the different performance parameters. Finally we concluded that the blended fuel having the better performance than Diesel in different aspects.

Keywords: Biodiesel, Transesterification, Vegetable Oils, Performance Parameters, Diesel Engine, Blended Fuel, Diesel.

1. INTRODUCTION

Bio-fuel is liquid fuel produced from plant origin .It can either be Biodiesel or ethanol. Liquid fuels from plant origin. Biodiesel is Diesel obtained from organic oils, mostly vegetables oils. Biodiesel is produced by modifying vegetable oils and reducing their viscosity by various methods. Ethanol is produced from sugar and starch. The energy challenge is especially acute in the transport sector, as most vehicles will continue to rely on liquid fuels for the decennia to come. Diesel and petrol (gasoline), obtained from fossil oil, will gradually be replaced by renewable liquid fuels, which are called bio-fuels. The most important among them are pure plant oil, Biodiesel (Diesel derived from PPO) and ethanol made from starch or sugar. The crops that are used for bio-fuel production are called **energy crops**; these include palm, soya bean, rice bran, olive oil , panama , sunflower , coconut , Jatropha , peanut , gingelly etc for biodiesel production and sugar cane, sweet sorghum, cassava, etc for ethanol production.

In this study we analyzed the performance of different bio-fuels from soya bean, palm oil and rice bran oil on the single cylinder water cooled Diesel engine; also we compared the results obtained from these fuels with the results of conventional fuel (Diesel). Finally we concluded that the bio fuels having better performance than Diesel in different aspects.

2. NOMENCLATURE

ASTM	--	American Society for Testing and Material
B100	--	100% bio-diesel
B10	--	10% bio-diesel
B20	--	20% bio-diesel
B30	--	30% bio-diesel
CO	--	Carbon Monoxide
CO_2	--	Carbon dioxide
DF	--	Diesel fuel
FFA	--	Free Fatty Acids
BD	--	Bio-diesel
RBD	--	Rice bran oil Bio-diesel
RB10	--	10% Biodiesel of Rice bran oil
RB20	--	20% Biodiesel of Rice bran oil
RB30	--	30% Biodiesel of Rice bran oil
PBD	--	Palm oil Bio-diesel
PB10	--	10% Biodiesel of Palm oil
PB20	--	20% Biodiesel of Palm oil
PB30	--	30% Biodiesel of Palm oil
SBD	--	Soya been oil Bio-diesel
SB10	--	10% Biodiesel of Soya been oil
SB20	--	20% Biodiesel of Soya been oil
SB30	--	30% Biodiesel of Soya been oil
T_1	--	Air inlet temperature (^{0}C)
T_2	--	Engine head water inlet temperature (^{0}C)
T_3	--	Engine head water outlet temperature (^{0}C)
T_3	--	Calorie meter water inlet temperature (^{0}C)
T_4	--	Calorie meter water outlet temperature (^{0}C)
T_5	--	Exhaust gas inlet temperature (^{0}C)
T_6	--	Exhaust gas outlet temperature (^{0}C)

3. HISTORY OF BIODIESEL

The process to obtain fuel from a fat is not a new process. It was as early as 1853, when scientists E. Duffy and J. Patrick conducted the first transesterification of a vegetable oil, many years before the first Diesel engine became fully functional. Transesterification is the processing of using an alcohol, such as ethanol or methanol, in the presence of catalyst like sodium hydroxide or potassium hydroxide, to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oil with glycerol as by-products.

We may say the first vehicle Biodiesel-powered was Rudolf Diesel's prime model, a single 10 feet iron cylinder with a flywheel at its base, that ran with this fuel for the first time in Augsburg, Germany on August10, 1893, later he demonstrated his engine powered by peanut oil-a biofuel, receiving the "Grand Prix" at the world Fair in pairs, France in 1900. Diesel believed that the utilization of a biomass fuel was the future of his engine, as he stated in his 1912 speech saying "the use of vegetable oils for engine fuels may seem insignificant today, but such oils may become, in the course of time, as important as petroleum and the coal-tar products of the present time".

Today, environmental impact concerns and a decreasing cost differential made biomass fuels such as Biodiesel a growing alternative and, in remembrance of Rudolf Diesel first German run, August 10 has been declared International Biodiesel Day.

3.1 Technical Aspects of bio-fuel:

- Major liquid bio fuels –straight or recycled vegetable oils (SVO or RVO), Biodiesel and ethanol, blended with petroleum products or without blending, can be used in many applications. The applications include all areas in which petrol or Diesel can be used in many diverse sectors such as transport, railways, marine, electricity generation, mining, agriculture, industry, commerce, defence and other multifunctional platforms.
- Bio-fuels improve the properties of petroleum fuels and engine performance, and reduce health harming toxic emissions. The quality standards and process for manufacture of bio-fuels are well established in the world and achieving increasing degree of efficiency and economies of scale. Bio-fuels are safer and easy to handle, store, transport, blend and use. They are easily biodegradable with petroleum products are not. Minor technical drawbacks are easily addressed.
- Eco-friendly ethanol offers a unique opportunity as an ideal replacement of lead. All large v1ehicle and engine manufacturers offer warranties for blends of ethanol and Biodiesel.

3.2 Origin and Purpose of the Bio-fuel:

- The purpose is to assess the feasibility for the production of Biodiesel.
- For the scope of bio-fuels are defined as liquid fuels of plant origin that can partially or totally replace fossil petroleum in all its uses. Bio-fuels have been examined, namely ethanol, vegetable oils and bio-Diesel.
- It is important to mention at the outset that his has not been about the whole range of alternative sources of renewable energy, which generally include solar power, wood, electricity and other non-petroleum products.
- It has been about liquid bio-fuels derived from agricultural crops that can be used in internal combustion engines for transportation and other related purposes.
- Ethanol is produced from a wide range of feed stocks such as cassava, sugarcane and sweet sorghum, maize, wheat and sugar beet and is used as a gasoline substitute or as an additive.
- Biodiesel can be obtained from most vegetable oils including Mahuwa, Pongamiya, Oil palm, Rapeseed, soybeans, sunflower, peanut, and gingelly and tree seeds. It can be used on its own or blended to any proportion with fossil Diesel. The intention is not to suggest that fossil fuels should be replaced by bio-fuels.
- Persistent fuel price increases, potential disruption of supplies and foreign exchange shortages threaten energy security and slow down the rate of economic development.
- Bio-fuels will not displace land and agricultural resources for food security, but will stimulate investment in agriculture by opening new markets for farmers who produce the feed stocks for bio-fuels and ensure access to food and better living conditions.
- The bio-fuel initiative presents an opportunity for the region to produce its own renewable energies.
- The rise in oil prices has made bio-fuels to become viable alternative sources of energy. Even if fuel prices were to fall (which is highly unlikely in the long term), fuel production through farming would create massive increases in rural employment, and is fully in line with the Kyoto protocol on greenhouse gases (GHG) and the recommendations of the World Summit on Sustainable Development (WSSD).
- All the countries were called upon to consider bio-fuel production as a major priority and to take immediate action to avoid oil price induced crises, by creating the

necessary harmonized legal and institutional frame work to promote the production and use of bio-fuels.

3.3 Types Seeds:

Jatropha: Jatropha is ranked in the sixth place because it has not yet been commercially grown in the region, although the potential is there. There is still a lot to be discovered in terms of its agronomic suitability to produce the required volume for Biodiesel.

Soybeans: Soybean is ranked second because of the same reasons as above. It is already widely grown by both large and small holder farmers as a food crop and an industrial crop. Soybean is used for vegetable oil and animal feed. Expanded use for Biodiesel will create additional demand and stimulate production, and this can be achieved with in one season by increasing the area under production.

Oil palm: Oil palm scores high for Biodiesel in terms of oil yield and capacity to produce large volumes in those parts of the region with suitable climate. Factors not in its favours include the time lag to full production and the fact that most parts of the region do not have the right climate for palm oil production. It is ranked third place.

Sunflower Seed: Sunflower seed is ranked fourth because compared to soybean its oilcake is not easily marketable for stock feed, but its production can be quickly expanded for Biodiesel.

Sweet Sorghum: Although not yet widely grown as a commercial crop, sweet sorghum can be grown in drier parts of the region with benefits for small-scale farmers. It can be used to complement sugar cane for the production of ethanol, while the by-products will be used for animal feed. It is ranked fifth place.

Peanut Seeds: Peanuts, or “groundnuts” as they are known in some parts of the world, are the edible seeds of a legume, Arachis hypogea and they are high in protein, oil and fiber. Peanuts produced in the U.S. are mostly used in food and confection products, but more than 50 percent 0f the worldwide production is crushed for its oil.

Gingelly Seeds: Gingelly oil is another name for sesame oil. It’s also known as teal oil. Sesame oil, or teal oil, is a Light yellow, emulsified liquid with a mild odor and unobtrusive taste. It contains high levels of anti-oxidants, which preserve its chemical composition. It has a long shelf life and resists becoming rancid. Storing the oil in a dark glass bottle will preserve it for longer periods.

In the present study, three types of bio-fuels from Rice bran grains, Soya bean seeds and Palm oil seeds at different compositions were tested on a single cylinder 4-stroke diesel engine.

Rice Bran Oil:

- Unrefined rice bran oil (UNRFRBO) with high free fatty acids (FFA) is used as a source for the production of unrefined rice bran oil methyl ester (UNRFRBOME). Three-stage transesterification process is successfully used.
- Initially, the FFA of UNRFRBO is reduced to 0.8% by using two stages of esterification process with methanol in the presence of acid (H_2SO_4) as a catalyst.
- Finally, Biodiesel has produced.

Fig-1: Rice bran grains

Soya Bean Oil:

- Extracting oil from soybeans requires pre-treatment of the grains. Pre-treatment includes operations of cleaning and drying, de-hulling and grinding.
- Use of mechanical presses, solvent extraction, supercritical fluid extraction and microwave-and ultrasound assisted oil extraction are the major processes practiced for oil extraction from soybeans.

Fig-2: Soya Bean Seeds

Palm Olive Oil:

- The Palmolive oil is extracted from Palmolive seeds by press work. Palms are ever green, most tropical plant in the plant plamae. There are 25000 species of palms and This is the largely cultivated crop

Fig-3: Palm Olive Seeds

4. METHOD OF BIO-DIESEL PRODUCTION:

4.1 Transesterification:

The process of production of Biodiesel involves reaction of vegetable oil with methanol or ethanol employing a catalyst such as sodium or potassium hydroxide. In this process the reaction that takes place is called **"Transeserification"**, which results in formation of Biodiesel and glycerol (glycerin). The methanol present the glycerin phase is removed by distillation and glycerin concentrated by removal of water. The Biodiesel is separated from the glycerin of higher density by settling or centrifuging. The glycerin in crude form can be processed and distilled to make various grades of glycerin that can be sold to various consumers. A water wash may be given to Biodiesel to remove impurities from it including methanol, catalyst and any remaining free glycerin.

Transesterification is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except than an alcohol is used instead of water. This process has been widely used to reduce the high viscosity of triglycerides. The transesterification reaction is represented as follows

$$\underset{\text{Ester}}{RCOOR^1} + \underset{\text{Alcohol}}{R^2OH} \leftrightarrow \underset{\text{Ester}}{RCOOR^2} + \underset{\text{Alcohol}}{R^1OH}$$

Transesterification is one of the reversible reactions and proceeds essentially by mixing the reactants. However the presence of a catalyst (a strong acid or base) accelerates the conversion. In the present work the reaction is conducted in the presence of base catalyst.

4.2 Base-Catalyzed Processes:

The base-catalyzed transesterification of vegetable oils proceeds faster than the acid catalyzed reaction. Due to this reason, together with the fact that the alkaline catalysts are less corrosive than acidic compounds, industrial processes usually favor base catalysts, such as alkaline metal alkoxides and hydroxides as well as sodium or potassium carbonates. The first step is the reaction of the base with the alcohol, producing an alkoxide and the protonated catalyst. The nucleophilic attack of the alkoxide at the carbonyl group of the triglyceride generates a tetrahedral intermediate from which the alkyl ester and the corresponding anion of the diglyceride are formed.

4.3 Production Procedure:

- Take 800 ml of vegetable oil in a beaker which is perfectly cleaned and without moisture content.
- Heat the oil up to 60^0C on a stirring hot plate of uniform temperature to be maintained.
- Take the methanol of 225 ml (which is used to reduce the viscosity and as well as to adopt the properties nearer to the petro Diesel) and also take 16 grams of KOH flakes (which is used as a catalyst).
- Dissolve the KOH pellets in Methanol completely by using stirrer.
- This solution (alkali – catalyzed base) is further mixed with raw vegetable oil which is heated at 60^0C. Use stirrer to mix the solution completely.
- Uniform stirring should be maintained and should be stirred about 30 min.
- After this process, take off the beaker from the stirrer and poured into a separating funnel.
- After 12-16hrs (about an overnight) we can observe the two layers separated.
- The top layer is crude Bio-Diesel and the bottom layer is glycerol.
- By using a separating funnel we can separate the Bio-Diesel and glycerol.
- The crude Bio-Diesel contains dissolved impurities and these can be removed by an older technique **washing process.**

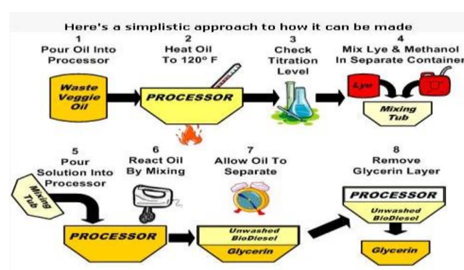

Fig-4: Layout of Transesterification Process

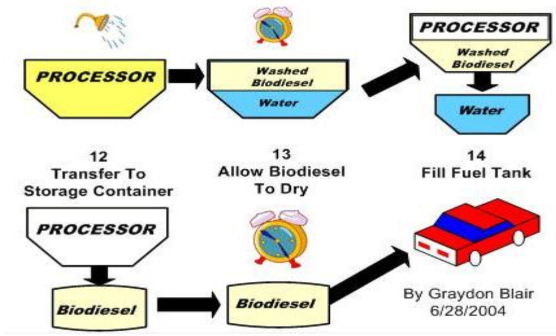

Fig-5: Layout of Water washing

5. EXPERIMENTAL SETUP:

The present study is carried out to analyze the performance of a single cylinder 4-stroke water cooled diesel engine based on the different performance parameters with Diesel and Bio-Diesel in different compositions.

Fig-6: Diesel Engine

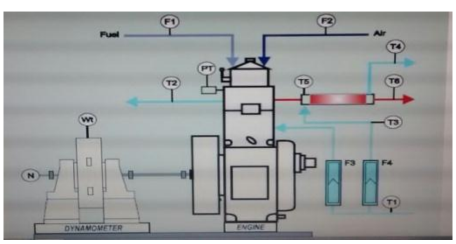

Fig-7: Experimental Setup

Table-1: Engine Specifications

Number of cylinders	Single cylinder Diesel Engine
Number of Strokes	4- Stroke
Fuel	Diesel
Made	Kirloskar
Rated Power	5 HP
Cylinder bore & Stroke	80mm*110mm
Compression Ratio	16.5:1
Cylinder Capacity	553cc
Speed	1500rpm
Starting	Hand Cranking
Load Type	By using Break Drum
Break Drum Diameter	0.2m
Type of cooling	Water cooled

5.1 Experimental Procedure:

The present experimental study involves two types of tests to find the different performance parameters. One is performance test and another one is retardation test.

5.1.1 Performance test procedure:

- Check Fuel in Tank.
- Allow fuel and Start Engine.
- Allow some time for stabilized the Speed.
- Take down the spring balance readings in table.
- Note down the time for 10ml fuel consumption.
- Take the manometer reading in 'mm'.
- Take the temperature Readings at different points: (i) Air inlet temperature (ii)Engine Head water Inlet & outlet temperatures (iii) Calorie meter water Inlet & outlet temperatures (iv) Exhaust gas Inlet & outlet temperatures.
- Repeat the above procedure with different loads and tabulate all the readings.

5.1.2 Retardation test procedure:

- Start the engine and allow some time to stabilize.
- Cutoff fuel supply to the engine.
- Take the time to reduce the speed of different values.
- Again fuel supply is given and engine is brought back to rated speed.
- Then apply the known load by using dynamometer.
- Again cutoff the Fuel supply and note the time to decrease the speed to various values as no load condition
- Tabulate all the readings.
- Plot the graph between the speed versus time with load and no load conditions.
- Finally calculate Frictional Torque.

6. RESULTS & DISCUSSION:

6.1 Results:

The aim of this experimental study is to analyze the performance parameters of different composition of bio-fuels with respective to the conventional Diesel fuel. Also the present work focused on the comparison of parameters among all the bio-fuels. Finally, the obtained results were plotted.

Table-2: Summarized Results-1:

Type of Fuel	B.P. (KW)	η_{bth} (%)	I.P. (KW)	η_{ith} (%)	η_m (%)
DIESEL	0.4768	7.57	2.7012	42.98	16.82
RB10	0.5057	7.58	2.9456	46.43	15.65
RB20	0.414	6.20	3.174	52.90	12.32
RB30	0.4389	6.77	2.990	50.39	13.57
SB10	0.517	7.76	2.127	33.24	22.12
SB20	0.4514	7.37	2.511	44.12	16.35
SB30	0.5344	8.58	3.174	55.21	14.53
PB10	0.5132	7.51	2.50	32.09	19.37
PB20	0.4772	7.31	2.017	32.64	21.03
PB30	0.5691	9.08	4.85	83.24	9.24

Table-3: Summarized Results-2:

Type of Fuel	SFC (Kg/KW-hr.)	A/F	F.P. (KW)	N (RPM)	T_6 (^{0}C)
DIESEL	1.323	47.76	2.20	1552	117
RB10	1.332	47.88	2.44	1570	149
RB20	1.85	54.42	2.82	1565	147
RB30	1.310	54.61	2.56	1562	136
SB10	0.988	47.88	1.61	1567	125
SB20	1.256	55.91	2.06	1565	129
SB30	0.948	50.43	2.64	1557	117
PB10	1.352	51.17	2.08	1577	130
PB20	1.336	49.24	1.54	1523	110
PB30	0.906	54.42	4.28	1565	136

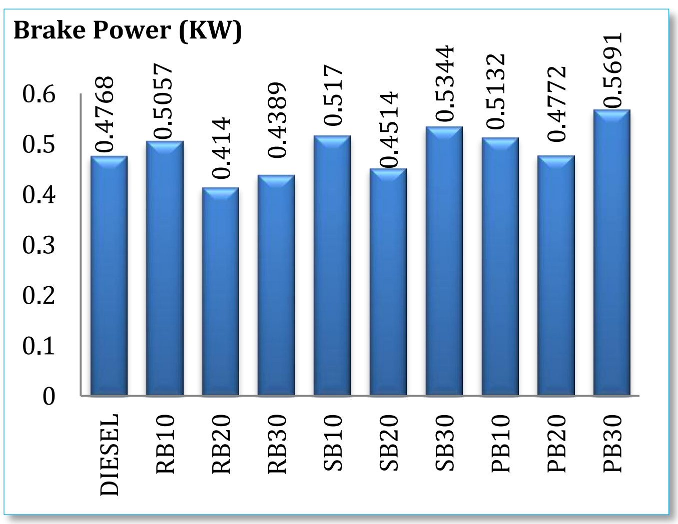

Chart-1: Brake Power at constant load

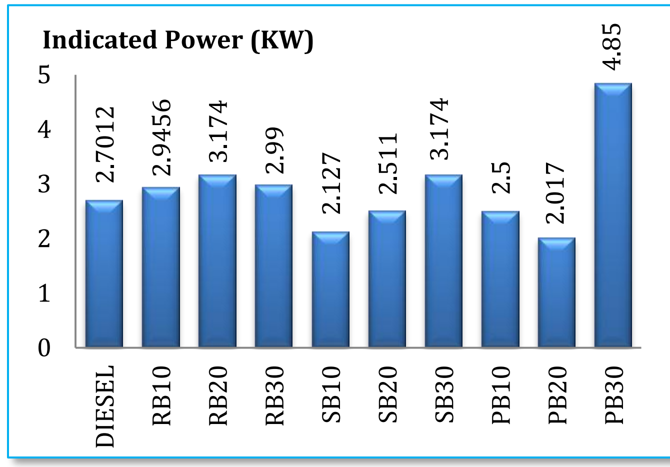

Chart-2: Indicated Power at constant load

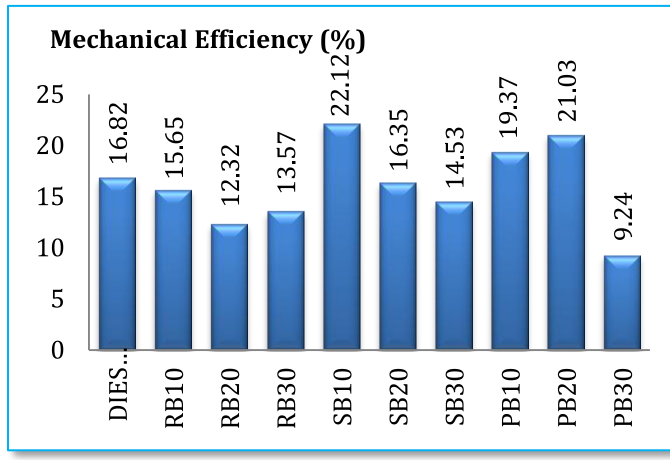

Chart-3: Mechanical Efficiency at constant load

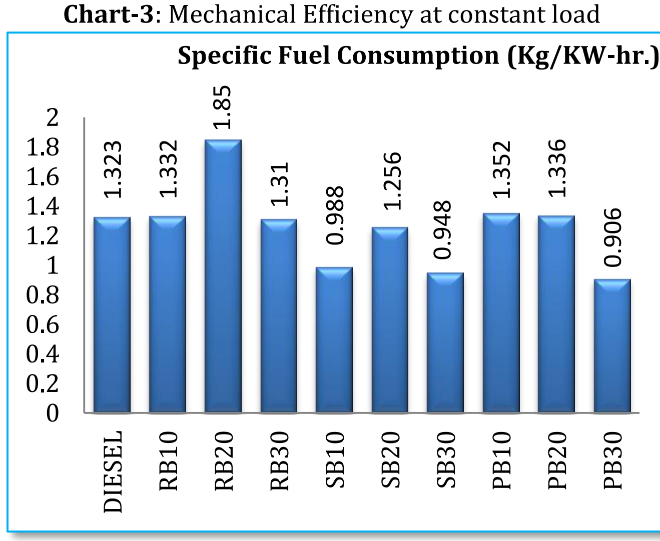

Chart-4: Specific Fuel Consumption at constant load

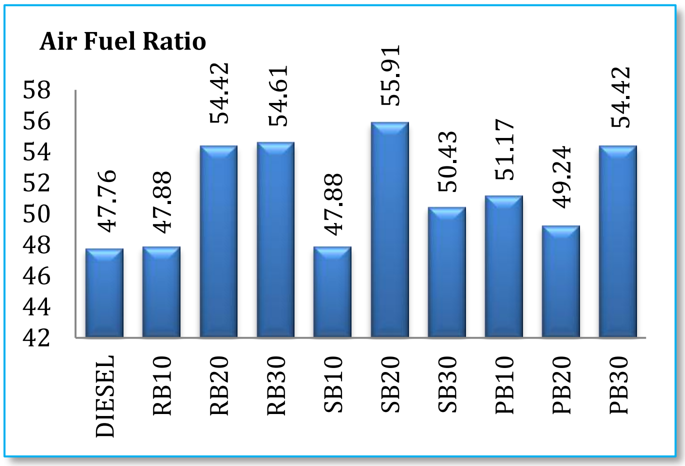

Chart-5: Air-Fuel Ratio at constant load

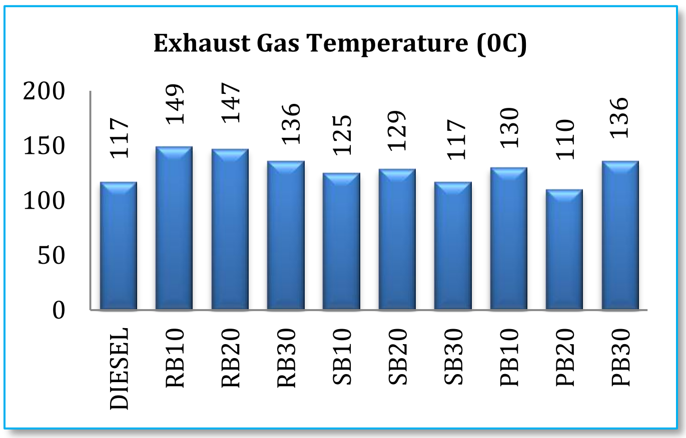

Chart-6: Air-Fuel Ratio at constant load

6.2 Discussion:

From the Chart-1 plotted above, it is clear that the brake power produced by the engine is higher for SB30, PB30 and SB10 fuels. But the frictional losses are also higher value when using PB30. Therefore the SB30 is preferable than the remaining bio-fuels.

From the Chart-2 plotted above, the indicated power is higher for SB30, RB20 and PB30 bio-fuels. PB30 having a lesser value of mechanical efficiency, therefore the remaining two types of fuels is more preferable than the PB30.

From the Chart-3 plotted above, it is analyzed that the mechanical efficiency of the engine is more while using the SB10 bio-fuel.

From the Chart-4 plotted above, it is clear that the rate of fuel consumption is very less while using PB30, SB30 and SB10.

The Air-fuel ratio must be higher value for a good fuel. From the Chart-5 it can be say that the SB20, RB20 and PB30 are the good fuel in Air-fuel ratio point of view.

The exhaust temperature is also plays an important role to reduce the air pollution global warming. Here, from the cahrt-6, we can say that the temperature of the exhaust gases is less for PB20 and SB30 when compared to the conventional Diesel Fuel.

7. CONCLUSION

From the experimental results obtained while operating a single cylinder Diesel engine with bio-fuels from vegetable oils and their Diesel blends it can concluded that the Vegetable oils, based methyl esters (Biodiesel) can be directly used in Diesel engines without any engine modification. Also the results are more favorable for the bio-fuel extracted from the soya beans vegetable oil than the conventional Diesel and other bio-fuel blends.

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