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Study of Brake Thermal Efficiencies of Blend Fuels Using CVCRM Engine Test Rig

Dr. D. R. Prajapati*, Gurpreet Singh Sudan**
*Assistant Professor in the department of Mechanical Engineering, PEC University of Technology (formerly Punjab Engineering College), Chandigarh-160012 (India).
**Assistant Professor in the department of Mechanical Engineering, Lovely Professional University, Phagwara (Pb.)-144402 (India).

Abstract— ***During the last century, the consumption of energy has increased considerably due to the change in the life style and the significant growth of population. This increase of energy demand has been partially met by the use of fossil resources, which caused the crises of the fossil fuel depletion, the increase in its price and the serious environmental impacts such as global warming, acidification, deforestation, ozone depletion, eutrophication and photochemical smog. Bio-fuels appear to be a solution to substitute fossil fuels, because resources for it will not run out (as fresh supplies can be re grown), they are becoming cost wise competitive, appear to be more environmental friendly and are rather accessible to distribute and use as applicable infrastructure and technologies exists and are readily available. Break thermal efficiencies have been computed for various blends of soya and mustered oils with petrol at different engine loads in computerized variable compression ratio multi-fuel (CVCRM) engine test rig. It is concluded that out of the two soya-bean oil blends, 20-PRS shows the higher break thermal efficiency compared to 15-PRS at the load of 7.5 KG also. It means that the blend 20-PRS shows the higher break thermal efficiencies compared to 15-PRS at all the three loads.***

Index Terms — **Break Thermal Efficiencies, Bio Fuels, CVCRM) Engine Test Rig and Engine Performance.**

I. INTRODUCTION

Two of the main contributors of this increase of demand in energy have been the transportation and the basic industry sectors. The transport sector is a major consumer of petroleum fuels such as diesel, gasoline, liquefied petroleum gas (LPG) and compressed natural gas (CNG). The demand for transport fuel has been increasing and expectations are that this trend will remain unchanged for the coming decades. In fact, with a worldwide increasing number of vehicles and a rising demand of emerging economies, demand will probably rise even harder. Increase in demand in transport increases the fossil fuel demand. However, resources of these fuels are running out, prices of fossil fuels are expected to rise and the combustion of fossil fuels has detrimental effects on the climate. The expected scarcity of petroleum supplies and the negative environmental consequences of fossil fuels have spurred the search for renewable transportation bio-fuels.

The concept of using vegetable oil as a transportation fuel oil goes back to 1893, when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. Vegetable oil is one of the renewable fuels. Vegetable oils have become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. Vegetable oils have the potential to substitute a fraction of petroleum distillates and petroleum-based petro chemicals in the near future. The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise 90 to 98% triglycerides and small amounts of mono and diglycerides.

Vegetable oils are liquid fuels from renewable sources; they do not over-burden the environment with emissions. Vegetable oils have potential for making marginal land productive by their property of nitrogen fixation in the soil. Their production requires lesser energy input in production. They have higher energy content than other energy crops like alcohol. They have 90% of the heat content of diesel and they have a favorable output/input ratio of about 2–4:1 for un-irrigated crop production. The current prices of vegetable oils in world are nearly competitive with petroleum fuel price. Vegetable oil combustion has cleaner emission spectra and simpler processing technology. But these are not economically feasible yet and need further R&D work for development of on farm processing technology. Due to the rapid decline in crude oil reserves, the use of vegetable oils as diesel fuels is again promoted in many countries. Depending on climate and soil conditions, different nations are looking into different vegetable oils for diesel fuels. For example, Soyabean oil in the USA, rapeseed and sunflower oils in Europe, palm oil in Southeast Asia (mainly Malaysia and Indonesia), and coconut oil in Philippines are being considered as substitutes for mineral fuel.

These usually contain free fatty acids (FFAs), water, sterols, phospholipids, odorants and other impurities. Different types of vegetable oils have different types of fatty acids. The advantages of vegetable oils as diesel fuel are their portability, ready availability, renewability, higher heat content (about 88% of D2 fuel), lower sulfur content, lower aromatic content, and biodegradability. The main disadvantages of vegetable oils as diesel fuel are high viscosity, low volatility, and the reactivity of unsaturated

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hydrocarbon chains. The injection and atomization characteristics of the vegetable oils are significantly different than those of petroleum-derived diesel fuels, mainly as the result of their high viscosities. The vegetable oils, as alternative engine fuels, are all extremely viscous with viscosities ranging from 9 to 17 times greater than that of petroleum-derived diesel fuel.

II. NOMENCLATURE

Following terms are used in this paper:

CVCRM = Computerized variable compression ratio multi-fuel

p = Pressure (in bar)

θ = Crank angle (in degree)

V = Volume (in %)

MFB = Mass Fraction Burnt (in %)

B.P = Brake Power (in KW)

EEOC = Estimated end of combustion angle

15PRS = Blending of 15% soya-bean oil with the petrol

20PRS= Blending of 20% soya-bean oil with the petrol

15PRM = Blending of 15% mustard oil with the petrol

20PRM= Blending of 20% mustard oil with the petrol

η_{BTE} = Break thermal efficiency

III. LITERATURE REVIEW

Various efforts have been made to use various alternative fuels and literature review is summarized in this section.

Dunn et al. (1996) worked on the new term approaches for improving the low temperature properties of triglyceride oil derived fuels for direct–injection compression ignition engines. This work explores two near term approaches for improving low temperature flow properties of methyl esters. The first approach, winterization, involves equilibrium a quiescent mixture of methyl esters at a temperature between its cloud point and pour point. The second approach involves treatment with off-the shelf cold flow additives. Results showed that additive treatment affect the cloud point or viscosity. Ale (2003) presented that, every engine is designed for a particular fuel and any change in fuel composition may affect the engine performance. Kerosene has been blended with petrol and diesel separately. Fuels mixed in different proportions were allowed to run at low engine idling speed, the carbon monoxide emission varied from 0.15% to 0.23% and unburned hydrocarbon from 260 ppm to 435 ppm respectively when proportions of kerosene in petrol was increased. Yadav et al. (2005) worked on effect of blending kerosene with petrol and diesel. Five fuel-adulterant mixtures in different proportions by volume were prepared and individually tested for density and kinematic viscosity. No appreciable density variation at different levels of adulteration was observed. Density was within the prescribed value even at higher adulteration.

Murali Krishna at al. (2006) performed the investigation to study the exhaust emissions from a single cylinder spark ignition (SI) engine with kerosene blended gasoline with different versions of the engine, such as conventional engine and catalytic coated engine with different proportions of the kerosene ranging from 0% to 40% by volume in steps of 10% in the kerosene-gasoline blend. Rao et al. (2008) worked on improving the performance of C.I. engine using biodiesel prepared from pongamia, jatropha and neem oil. Blends prepared were B10, B20 and B40 of the above fuel. Various properties like density, viscosity and flash point of the fuel blends were calculated. The various parameters like properties, performance and emissions results of the blends were compared with the diesel fuel. The blend B20 shows the closer performance to that of the diesel fuel. Pangomia methyl ester gives the better performance as compared to jatropha and neem oil methyl ester. Das et al. (2009) worked on the storage stability of the karanja oil methyl ester and examined various parameters like peroxide value, viscosity etc. The stability of the methyl ester was studied under different storage conditions for a period of 180 days. The stability was improved using different antioxidants such as pyrogallol, propyl galate, Tetra butylated hydroxyl toluene and Tetra butylated hydroxyl anisole. The effectiveness of the three antioxidants propyl galate, Tetra butylated hydroxyl toluene and Tetra butylated hydroxyl anisole was examined at different loading conditions. Anbumani et al. (2010) worked on two edible plant oils mustard and neem as diesel substitute. Oils were blended in the ratios of 10:90, 15:85, 20:80 and 25:75. Engine was run at different loads at constant speed on each blend and on the pure diesel and concluded that the performance of 20% of blend showed the closer performance to the diesel fuel and the performance of Mustard oil blend was better than the performance of Neem oil. Parameters like specific fuel consumption, thermal efficiency and peak pressure gave the satisfactory results.

Ramaraju et al. (2011) worked on production of biodiesel using punnakka oil and produced a biodiesel using two stage process, first by acid and then alkaline esterifiication. The acid value of the oil was reduced by acid esterification. The product from this stage was subjected to alkaline esterification to produce biodiesel. The various parameters like reaction temperature, catalyst concentration and reaction time were established. The properties were closer to that of Biodiesel. Martin et al. (2011) worked on the performance of compression ignition engine using blends of the cotton seed oil with diesel in C.I. engine. Performance, emission and combustion parameters were calculated at various loads using blended biodiesel and compared with the neat diesel. The 60% blend of biodiesel with the conventional diesel fuel gives the maximum efficiency and reduction in smoke or reduction in carbon monoxide and hydrocarbon emissions. The details of apparatus and preparation of bio-fuels are discussed in the next section.

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IV. DESCRIPTION OF APPARATUS AND PREPARATION OF BIO-FUELS

The computerized variable compression ratio multi-fuel engine test rig is an automatic engine which makes our work easier by calculating the various parameters. Both petrol and diesel fuels may be used on this engine. The compression ratio can be varied from 5:1 to 20:1. The load can also be varied from 0-10 KG. By varying the load or the compression ratio the efficiencies and the specific fuel consumption may be calculated. The minimum fuel required for proper engine functioning is 5 litre. The engine contains two sensors one for petrol and other for diesel. Their main function is to decide the range of the fuel level. Specification of computerized variable compression ratio multi-fuel engine test rig is shown in Table I and Figure 1 shows the computerized variable compression ratio multi-fuel engine test rig

Table I Specifications of Computerized Variable Compression Ratio Multi-Fuel Engine Test Rig

Make	LEGION BROTHERS
BHP	3-5 HP
Speed	1450-1600 r.p.m. variable governed speed
No. of cylinder	1
Compression ratio	5:1 to 20:1
Bore	80 mm
Stroke	110 mm
Type of ignition	Spark ignition (time adjustment: 0-70 degree ATDC: 0-70 degree BTDC or Compression ignition
Method of loading	Eddy current dynamometer
Method of cooling	Water

Fig.1 Computerized Variable Compression Ratio Multi-Fuel Engine Test Rig

A. Preparation of Bio-Fuel from Vegetable Oil

Production of bio-diesel was carried out using a bio-fuel reactor. Bio-fuel reactor contains magnetic stirrer, condenser, flask, pump and the tub. The raw material used was vegetable oil (mustard oil or refined Soyabean oil). One litre of vegetable oil along with methanol (in appropriate quantity, depending on the oil used) was mixed in the round bottom flask. 5 gm of catalyst (potassium hydroxide) was added in the mixture, as shown in Fig. 2(a) similarly, mixture of mustard oil is shown in Figure 2(b).

Fig. 2(A) Soyabean Oil Mixture before Starting the Operation

Fig. 2(B) Mustard Oil Mixture before Starting the Operation

The whole mixture (oil + catalyst + methanol) is heated up to the temperature of about 60 degree Celsius and is stirred at a constant r.p.m. For Soyabean oil, the whole process is allowed to run for 1 hour 30 minutes and for mustard oil the whole process is allowed to run for 1 hour 15 minutes approximately. When the process is over, the mixture is allowed to settle for at least 4 hours. Two layers are observed after settling of the mixture, the upper and the bottom layer. The ester is visible in the upper layer and the glycerol in the bottom layer. The layers are separated using separating funnel and the glycerol is removed from the mixture. After removing glycerol from the ester, the warm water is added to the remaining part of the ester. The mixture is shaken for 4 to 5 times and mixture is then kept undisturbed for next 1 hour. Again two layers are observed, the upper layer is of bio-fuel and the lower one is of impure solution of potassium hydroxide with the water. The potassium hydroxide solution is in the form of white precipitates. The bio-fuel is formed by separating the layers.

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B. YIELD OF BIO-FUEL

(i) Soyabean Mixed fuel:

Methanol used = 168 ml

Catalyst used = 5 gm

Time taken for experiment = 1.30 hours

Temperature = 61^{0} C

Maximum yield of bio-fuel = 900 ml

For Mustard oil,

Methanol used = 220 ml

Catalyst used = 5 gm

Time taken for experiment = 1.15 hours

Temperature = 59 ^{0} C

Maximum yield of bio-fuel = 983 ml

For soyabean oil 168 ml is the maximum amount of methanol, which may be added in the vegetable oil for the transesterification reaction and for the mustard oil, the maximum amount of methanol added is 220 ml. If more methanol is added then it remains un-reacted in the mixture and floats on the top surface which leads to the wastage of methanol and money. Next section deals with the computation of thermal efficiencies at different blends of fuels.

V. COMPUTATION OF BREAK THERMAL EFFICIENCY

The break thermal efficiency can be defined as the ratio of brake thermal power to the input fuel energy in appropriate units.

Therefore,

$$\eta_{BTE} = \frac{b.p}{mas \times calorific\ of\ fuel}$$

Table II Variation of thermal efficiency at various loads using only petrol

LOAD (in KG)	Thermal efficiency (%)
2.5	3.962
5.0	13.957
7.5	18.540

Table III shows the brake thermal efficiencies of engine with blending of 15% soya-bean oil with the petrol (15-PRS) with respect to change in the engine loads.

Table III Variation of thermal efficiency of 15-PRS fuel with respect to loads

LOAD (in KG)	Thermal efficiency (%)
2.5	6.569
5.0	13.866
7.5	18.117

Table IV shows the brake thermal efficiencies of engine with blending of 20% soya-bean oil with the petrol (20-PRS) with respect to change in the engine loads.

Table IV Variation of thermal efficiency of 20-PRS fuel with respect to loads

LOAD (in KG)	Thermal efficiency (%)
2.5	6.581744
5	15.11843
7.5	21.04831

Table V shows the brake thermal efficiencies of engine with blending of 15% mustard oil with the petrol (15-PRM) with respect to change in the engine loads.

Table V Variation of thermal efficiency of 15-PRM fuel with respect to loads

LOAD (in KG)	Thermal efficiency (%)
2.5	6.603
5.0	13.987
7.5	21.283

Table VI shows the brake thermal efficiencies of engine with blending of 20% mustard oil with the petrol (20-PRM) with respect to change in the engine loads.

Table VI Variation of thermal efficiency of 20-PRM fuel with respect to loads

LOAD (in KG)	Thermal efficiency (%)
2.5	6.715614
5	15.03791
7.5	20.36958

VI. ANALYSIS

Thermal efficiencies of various blends of bio-fuels are computed in the above section but their comparison and analysis is discussed in this section.

A. Comparison of Brake Thermal Efficiencies

Table VII shows the comparison of the brake thermal efficiencies of different bio-fuels used in the engine.

Table VII Comparison of Brake thermal efficiencies (η_{BTE}) of different bio-fuels

Load (In KG)	η_{BTE} of petrol	η_{BTE} of 15-PRS (%)	η_{BTE} of 20-PRS (%)	η_{BTE} of 15-PRM (%)	η_{BTE} of 20-PRM (%)
2.5	6.568578	3.962	6.581744	6.603235	6.715614
5.0	13.86644	13.95743	15.11843	13.9867	15.03791
7.5	18.116655	18.54013	21.04831	21.28297	20.36958

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The graphical comparison is shown in also represented in the graphical form as shown in Fig. 3.

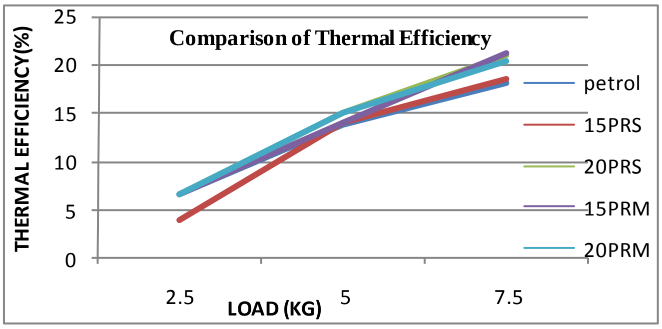

Fig 3 Brake thermal efficiency versus load

Following facts are observed from the Tables II to VII.

- **(i)** Out of the two soya-bean oil blends, 20-PRS shows the higher break thermal efficiency compared to 15-PRS at the load of 2.5 Kg.
- **(ii)** Out of the two soya-bean oil blends, 20-PRS shows the higher break thermal efficiency compared to 15-PRS at the load of 5 Kg.
- **(iii)** Out of the two soya-bean oil blends, 20-PRS shows the higher break thermal efficiency compared to 15-PRS at the load of 7.5 KG also. It means that the blend 20-PRS shows the higher break thermal efficiencies compared to 15-PRS at all the three loads.
- **(iv)** Out of the two mustard oil blends, 20-PRM shows the higher break thermal efficiency compared to 15-PRM at the load of 2.5 Kg.
- **(v)** Out of the two mustard oil blends, 20-PRM shows the higher break thermal efficiency compared to 15-PRM at the load of 5 Kg also.
- **(vi)** Out of the two mustard oil blends, 15-PRM shows the higher break thermal efficiency compared to 20-PRM at the load of 7.5 Kg.
- **(vii)** At the load of 2.5 Kg, the blend of 20-PRM shows the highest break thermal efficiency compared to other blends.
- **(viii)** At the load of 5.0 Kg, the blend of 20-PRS shows the highest break thermal efficiency compared to other blends.
- **(ix)** At the load of 7.5 Kg, the blend of 15-PRM shows the highest break thermal efficiency compared to other blends.

VII. CONCLUSION

An acceptable alternative fuel for engine has to fulfill the environmental and energy security needs without sacrificing operating performance. Vegetable oils can be successfully used in CI engine, through engine modifications and fuel modifications because vegetable oil in its raw form cannot be used in engines. It has to be converted to a more engine-friendly fuel called bio-diesel. Bio-fuels appear to be more environment friendly in comparison to fossil fuels, considering the emission of greenhouse gasses when consumed. Examples of those gasses are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The energy content of bio-fuels differs from conventional fuels. Total energy output per litre of bio-fuel is determined by the feedstock used region, where the feedstock is grown and production techniques applied. Currently, the cost of bio-fuel is high compared to conventional diesel oil because most of the bio-fuel is produced from pure vegetable oil. Extensive use of edible oils may cause other significant problems such as starvation in developing countries.

An attempt is made to compare the break thermal efficiencies of bio-fuels, prepared from the blending of soya-bean and mustard oils with petrol. It is concluded that the blend 20-PRS shows the higher break thermal efficiencies compared to 15-PRS at all the three loads. Similarly, the blend of 20-PRM and 20-PRS shows the higher break thermal efficiencies at the load of 2.5 KG and 5 Kg respectively. It is also found that break thermal efficiencies of blend fuels are either greater than or approximately equal to the break thermal efficiencies of using only petrol fuel, at various loads.

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Author's Biography

****D. R. Prajapati (Co-author)** is working as an Assistant Professor in the department of Mechanical Engineering, PEC University of Technology (formerly Punjab Engineering College), Chandigarh-160012 (India) since 16th July, 1999. He published more than 60 research papers in international and national journals of repute and in the proceedings of the conferences. He is also reviewer of 6 international journals. He also guided 2 Ph. D. and more than 13 post graduate theses and guiding 3 research scholars at present. He has also chaired international and national conference in India and abroad. He also organized two short term courses and one All India Conference for the faculty of technical institutions and industries. His e-mail ID is: drprajapati@pec.ac.in and praja_3000@yahoo.com (alternate)

Gurpreet singh sudan is an Assistant Professor in the department of Mechanical Engineering, Lovely Professional University, Jalandhar-Delhi G.T. Road (NH-1), Phagwara, Punjab (India). He has done his M.E degree in Mechanical branch from PEC University of Technology (formerly Punjab Engineering College), Chandigarh-160012 (India) and B.E degree in Mechanical branch from MBSCET, Babliana, Jammu-181101 (India). His e-mail ID is: sunnysudan@rediffmail.com