IOP Conf. Series: Materials Science and Engineering **377** (2018) 012199 doi:10.1088/1757-899X/377/1/012199

An experimental study on Performance of CI engine fuelled with waste cooking oil

A. Das[1] and M. D. Ghatak[1]
[1]NIT Arunachal Pradesh, Yupia, PapumPare, Arunachal Pradesh

manjula.ghatak01@gmail.com

Abstract. Day by day depletion of fossil fuel and their growing pollution has become a real concern for the researchers worldwide. Growing concern regarding energy resources and the environment has increased interest in the study of alternative sources of energy like wind energy, solar energy, biomass, bio-diesel etc. Now-a-days people are getting interest in bio-diesel to provide a suitable diesel oil substitute for internal combustion engines. It is found to be a promising field to reduce the dependence of India's foreign imports of oils. Biodiesel is an alternative fuel for conventional diesel engines and can be used without major modification of the engines. This study represents the effects of biodiesel obtained from waste frying oil (mustard oil) which is obtained from local restaurant and hotels, on 4-stroke direct injection engine performance and exhaust emissions. A comparative study of performance of normal diesel and various proportion blend of bio-diesels with normal diesel is done. Performance of diesel engine using varying blends of biodiesel like B5, B10 and B 15 is tested for this case.

1. Introduction

Energy is the most important aspect to economic and social development to improve quality of life. Majority of the current energy sources in the world are based on fossil fuels, which will someday deplete if we do not develop technologies that could utilize alternative fuels for energy supply. The consumption of energy demand around the world is growing faster than population growth [1]. In this century it is believed that crude oil and petroleum products will come very scare and costly[2]. Day to day fuel economy of engines is getting improved and that will be continued for years. But because of the substantial increase of the number of vehicle the demand of fuel increases rapidly [3]. This increment projection is estimated to increase up to 1.5% in 2030, due to great energy consumption in developing countries, especially in the Asian region [4].

The increasing demand for energy forces the major exporters of fuel energy around the world to find the alternative fuels to replace products based on fossil fuel, and not to be dependent on it. Sustainability is the main issue that causes the energy sector not being fully developed, thus various agencies are required to utilize new and renewable energy sources [5-6]. Biodiesel is one of the most promising alternative fuels to solve this problem. Biodiesel is renewable, biodegradable, and non-toxic and has almost very close property to that of diesel fuel[7]. It can be produced from vegetable oils, as well as animal fats. These oils, however, have high viscosity and is therefore cannot be directly used as fuel. In order to reduce viscosity, the raw oils must undergo trans-esterification process to remove glycerin as by product and esters, thus creating biodiesel. Biodiesel can operate in compression-ignition engines with little or no modification, similar to petroleum diesel. Moreover, biodiesel has more advantages regarding the engine wear, cost, and availability. When burned, biodiesel produces pollutants that are less detrimental to human health. In addition, it provides better lubricity as compared to diesel fuel. However, performance and emission characteristics of biodiesel-fuelled engine are important to consider. In general, combustion of biodiesel fuel in compression-ignition (CI) engines produces less smoke, particulate matter, carbon monoxide and hydrocarbon emission [8-9].

The broad vision behind India's integrated energy policy is to reliably meet the demand for energy services of all sectors including the transport sector in all parts of the country with safe, clean and convenient energy at the least-cost[10]. This must be done in a technically efficient, economically viable and environmentally sustainable manner using different fuels and forms of energy, conventional and non-conventional. In other words, the goal of the energy policy is to provide energy security to all. India's energy demand is expected to grow at an annual rate at 4.8 % over the next couple of decades [11]. Most of the energy requirements are currently satisfied by fossils fuel – coal, petroleum based product and natural gas [12]. Domestic production of crude oil can only fulfil 25-30 percent of national consumption, rest we are importing from other countries [13]. In these circumstances bio fuels are going to play an important role in meeting India's growing energy needs. At the same time the world reserves of primary energy and raw materials are obviously limited. According to an estimate, the reserves will last only another 218 years for coal, 41 years for oil and 63 years for natural gas, under a business- as usual scenario [14].

Biodiesel is a renewable fuel that can be produced from vegetable oils, animal fats, used cooking oil, and waste from the paper industry. It can be used in its neat form, or as a blend with conventional diesel fuel, in diesel engines without any modifications. Since biodiesel is produced from renewable, domestically grown feedstock, it can reduce the use of petroleum based fuels and possibly lower the overall greenhouse gas (carbon dioxide, methane, nitrous oxide & ozone) emissions from the use of internal combustion engines.

2. Materials and Methods

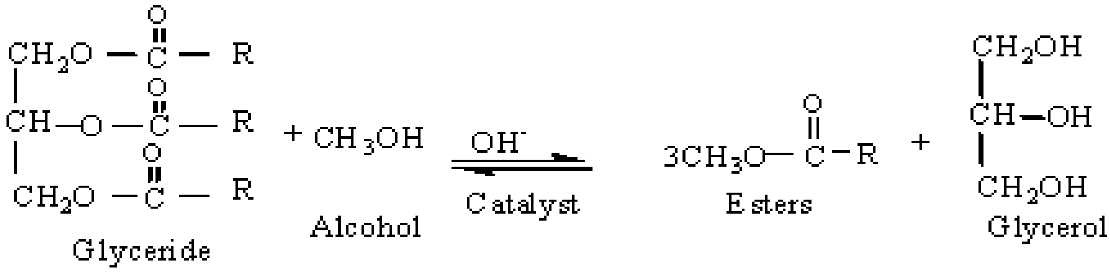
2.1 Transesterification reaction

The specific features of organic compound (such as the hydroxyl groups in alcohols) are responsible for the fact that many compounds can react with other compounds to form new compounds. The new may then belong to a different class of compounds. These structural features are also responsible for the differences in physical properties (melting point, boiling point, etc.) of the organic compounds.

In a variation of the formation of esters from acids and alcohols, an ester can react with other alcohol. In that case, the new alcohol is derived from the original ester and the new ester is derived from the original alcohol. Thus, an ethyl ester can react with methanol to from a methyl ester and ethanol. This process is called transesterification [15-17]. Transesterification of natural glycerides with methanol to methyl esters is a technically important reaction that has been used extensively in the soap and detergent manufacturing industry worldwide for many years. Almost all biodiesel is produced in a similar chemical process using base catalyzed transesterification as it is the most economical process, requiring only low temperatures and pressures while producing a 98% conversion yield. A successful transesterification reaction is signified by the separation of the methyl ester (biodiesel) and glycerol layers after the reaction time. The heavier co-product, glycerol, settles out and may be sold as is or purified for use in other industries, e.g. pharmaceutical, cosmetics, and detergents. After the transesterification reaction and the separation of the crude heavy glycerine phase, the producer is left with a crude light biodiesel phase. This crude biodiesel requires some purification prior to use.

Transesterification is extremely important for biodiesel. Biodiesel as it is defined today is obtained by transesterifying the triglycerides with methanol. Methanol is the preferred alcohol for obtaining biodiesel because it is the cheapest (and most available) alcohol [18]. However, for the reaction to occur in a reasonable time, a substance called catalyst must be added to the mixture of the vegetable oil and methanol. Enzymes, alkalis (e.g. NaOH, KOH) or acids can catalyze the reaction [19-20]. Among these alkalis transesterification is faster and hence it is used commercially.

IOP Conf. Series: Materials Science and Engineering **377** (2018) 012199 doi:10.1088/1757-899X/377/1/012199



2.2 Methodology

Waste frying oil (mustard oil) which is obtained from local restaurant and hotels contains many impurities in the form of sediments. This sediment present in the oil was removed using filter paper. Then the waste frying oil is taken in a round bottom flask and mixed with methanol in the ratio 1:6.A solution containing 0.1N HCL was poured into round bottom flask containing the oil alcohol mixture while stirring the mixture continuously. The mixture was then heated in a heating mantle at 80 deg. Celsius for 4h and then allowed to settle under gravity in a separating funnel. Out of two layers formed, upper layer is the Biodiesel and lower layer was of glycerol. The lower was separated out and ester was mixed with hexane in the same amount and shaken properly and again allowed to settle down for 24h. The remaining mixture from the purified ester was removed. Then the hexane was allowed to vaporize in the atmosphere by keeping the mixture open for 48 hours. The ester was then blended with diesel oil in various concentrations for preparing biodiesel blends, which were subsequently used in the engine performance tests. The level of blending for convenience is referred as BXX. The XX indicates the amounts of biodiesel in percentage in the blend (like a B05 blend is 05% biodiesel and 95% diesel oil).

3. Experimental set-up

Fig. 1 shows the test rig set up for the experimental study. It consists of a test-bed, a four stroke diesel engine, a dynamometer, a fuel tank, a data acquisition system, a computer, an operating panel, four exhaust emission analyzers, and various sensors to measure the oil pressure, the exhaust temperature at the manifold, etc.

Engine Specification:
Four cylinder 4 stroke inline diesel engine
Make: TATA (Indica)
Power: 10HP@1500 rpm
Bore: 75mm
Stroke: 79mm
Loading: Eddy current Dynamometer (Arm Length = 200mm)

Figure 1. experimental set-up

4. Results and Discussion

4.1 Properties of Fuel

Before testing engine performance the main properties of the fuel tested are shown in Table 1. The density of fuel is measured by density meter at 40ºC. The density meter has been calibrated with dry air and pure water. After some time the bio diesel has been sampled by sampling pump and reading were taken down. Calorific value of pure diesel and its blend with biodiesel has been successfully found out by using an apparatus called Bomb calorimeter. Kinematic viscosity of the fuel is measured by kinematic viscometer bath (220/440V, single/Three phase) using ASTM D-445 and D-2171 method. The other properties like cloud point, pour point, flash point, fire point, cetane index etc. are collected from literatures [21-24]. As shown in the table, pure diesel has the highest gross calorific value and the lowest viscosity. When diesel mixed with vegetable oil to make blends, it is found that the more percentage of vegetable oil in the blends, the higher of the viscosity and the lower the gross calorific value. Pure vegetable oil has the lowest gross calorific value and the highest viscosity.

Table1. Properties of Fuel

	Gross Calorific Value (MJ/Kg)	Viscosity (Poise)	Relative Density	Cetane Number	Flash point (ºC)	Fire point (ºC)	Pour Point (˚C)	Micro Carbon Residue (% wt)
Pure Diesel	45.535	0.0454	0.850	47.31 [21]	70 [22]	96 [23]	-16 [24]	0.0065 [21]
B05	42.851	0.0772	0.858	51.49 [21]	----	---	-6 [21]	0.0065 [21]
B10	40.481	0.1023	0.890	49.81 [21]	----	---	-9 [21]	0.0133 [21]
B15	39.358	0.2367	0.902	-----	----	---	----	----
B100	35.081	0.769	0.997	58 [21]	162 [22]	172 [23]	-5 [21]	----

4.2 Engine Performance

The diesel engine ran well on all the fuels mentioned above. There were no faults happening during the whole experiment process. The test results are plotted and explained in the figures 2, 3 And 4 for different blends of biodiesel.

4.3 Comparison of Performance

The followings are the graphical representations of the test results of engine brake specific fuel consumptions (BSFCs) for different blends of bio-fuels with the variation of load. The engine BSFC decreased with the increase of engine loads, as showed in the figure. The differences of BSFC are very small at different engine load, when using different fuels. The graphical representations also show the test results of the engine specific fuel consumption for different blends of fuels.

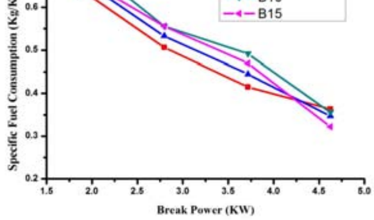


Figure 2. Specific Fuel Consumption Vs Break Power for normal diesel

IOP Conf. Series: Materials Science and Engineering **377** (2018) 012199 doi:10.1088/1757-899X/377/1/012199

Figure 2 represents the specific fuel consumption of normal diesel and various blends of bio-diesel (here B05, B10 and B15) with variation of load. The various blends of bio-diesel with normal diesel show very little variation compared to normal diesel. At low and medium load consumption of B05, B10 and B15 increases than normal diesel but not significantly. At higher load complete combustion of mustard oil decreases for higher blends such as B15 & B10.

It is seen that BSFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel. However with increase of percentage of biodiesel, BSFC decreases with respect to load and shows close results to that of diesel. This may be due to improved combustion, low viscosity, high volatility of the test fuels.

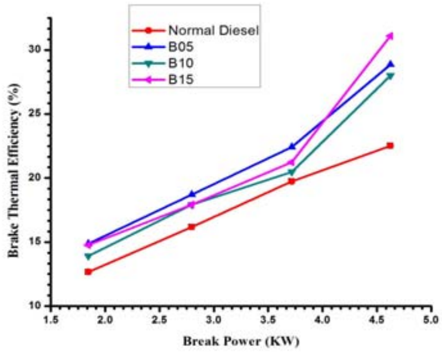


Figure 3. Brake Thermal Efficiency Vs Break Power

Figure 3 represents Brake Thermal Efficiency of normal diesel and various blends of bio-diesel (here B05, B10 and B15) with break power. It is found that brake thermal efficiency of all blends of bio-diesel is higher than that of normal diesel. Though at lower load B10 is more efficient than other two blends but at higher loads B15 becomes more efficient than that of diesel while other blends become less efficient.

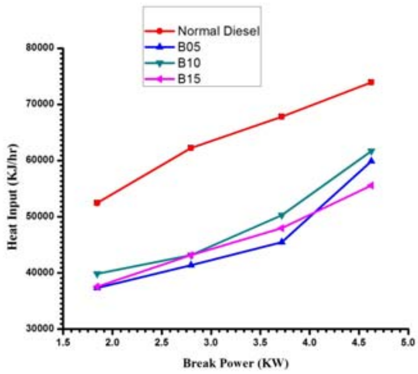


Figure 4. Heat Input Vs Break Power

Figure 4 represents heat input for normal diesel and various blends of bio-diesel (here B05, B10 and B15) with break power. It is found that heat inputs of all blends of bio-diesel are less than that of normal diesel foe every load condition. B05 emits less heat at lower load but increases significantly with the increase of load. B15 also gives nearly same value of heat input as B05. But at higher loads B15 sample emits less heat than all other samples.

5. Conclusion

The experimental results show that the engine performance run by waste cooking oil and its blends are comparable with the performance run by pure diesel fuel. The engine power output and the fuel consumption of the engine are almost the same when the engine is fueled with waste cooking oil and its blends compared with that of pure diesel. The results from the experiments prove that waste cooking oil and its blends are potentially good substitute fuels for diesel engine in the near future when petroleum deposits become scarcer. The use of 100% biodiesel, in diesel engine, is still theoretical and requires engine modification for a long run. But, the motto is to gradually shift these vegetable oil based fuels from petroleum based fuels or otherwise about 50 years from now the term 'Diesel or Petrol' will be aliens to the coming generation. Though a practical and theoretical study is necessary to find the emission characteristic of diesel engine fuelled by waste cooking oil and its blends.

References

[1] Patni Neha., Pillai Shibu G., Dwivedi Ankur H., 2011 Analysis of current scenario of Biofuels in India specifically Bio-diesel and Bio-ethanol, *Institute of Technology, Nirma University, Ahmedabad* **382** 08-10.

[2] Dharma. S. et. al., 2016 Optimization of biodiesel production process for mixed Jatropha curcas–Ceiba pentandra biodiesel using response surface methodology, *Energy Conversion and Managemen,* 115 178-190.

[3] Prabhahar M., Muralimanohar R., Sendilvelan S., Performance, 2012 Emission and Combustion Characteristics of a Direct Injection Diesel Engine with Pongamia Methyl Ester and Diesel Blends, *European Journal of Scientific Research* **73** 504-511.

[4] Patil Sanjay., Akarte Dr. M.M., 2012 Effect of Injection Pressure on CI Engine Performance Fuelled with Bio diesel and its blends, *International Journal of Scientific & Engineering Research* **03** 123-127.

[5] Jawalkar Ashish., Jagadish M., Mahantesh Kalyan., Merawade Madhusudhan., Navindgi M C., 2012 Performance and Emission Characteristics of Mahua and Linseed Biodiesel Operated at Varying Injection Pressures on CI Engine, *International Journal of Modern Engineering Research* **02** 1142-1149.

[6] Elango Thangavelu., Senthilkumar Thamilkolundhu., 2011 Combustion and emission characteristics of a diesel engine fuelled with Jatropha and diesel oil blends, *thermal science* **15** 1205-1214.

[7] Shahir. V.K. et.al., 2015 Comparative study of diesel and biodiesel on CI engine with emphasis toemissions—A review, *Renewable and Sustainable Energy Reviews* 45 686–697.

[8] Sathiyagnanam A.P., Saravanan C.G., 2011 Experimental Studies on the Combustion Characteristics and Performance of a Direct Injection Engine Fuelled with Bio diesel/Diesel Blends with SCR, *Proceedings of the World Congress on Engineering* **III** 6 – 8.

[9] Zhu Lei., Cheung C.S. ., Zhang W.G., Huang Zhen., 2011 Combustion, performance and emission characteristics of a DI diesel engine fueled with ethanol–biodiesel blends, *Fuel* **90** 1743-1750.

[10] Kamalesh. A. et. al., 2015 Biodiesel properties and automotive system compatibility issues, *Renewable and Sustainable Energy Reviews* **41** 777-798.

[11] Cetin Murat., Yuksel Fikret., 2007 The use of hazelnut oil as a fuel in pre-chamber diesel engine, *Applied Thermal Engineering* **27** 63–67.

[12] Randazzo Mário L., Sodré José R., 2011 Exhaust emissions from a diesel powered vehicle fuelled by soybean biodiesel blends (B3–B20) with ethanol as an additive (B20E2–B20E5), *Fuel* **90** 98–103.

[13] Ilkılıç Cumali., Aydın Selman., Behcet Rasim., Aydin Hüseyin., 2011 Biodiesel from safflower oil and its application in a diesel engine, *Fuel Processing Technology* **92** 356–362.

[14] Usta N., 2005 An experimental study on performance and exhaust emissions of a diesel engine fuelled with tobacco seed oil methyl ester, *Energy Conversion and Management* **46** 2373–2386.

[15] Murillo S., Mıguez L., Porteiro J., Granada E., Mora´n J.C., 2007 Performance and exhaust emissions in the use of biodiesel in outboard diesel engines, *Fuel* **86** 1765–1771.
[16] Nagarhalli M. V., Nandedkar V. M., 2011 Effect of injection pressure on emission and performance characteristics of Karanja bio diesel and its blends in C.I. Engine, *International journal of applied engineering research* **01** 104-107.
[17] Banapurmath N.R., Tewari P.G., Gaitonde V.N., 2012 Experimental investigations on performance and emission characteristics of Honge oil biodiesel (HOME) operated compression ignition engine, *Renewable Energy* **48** 193-201.
[18] Venkanna B.K., Wadawadagi Swati B., Reddy C. Venkataramana., 2009 Effect of Injection Pressure on Performance, Emission and Combustion Characteristics of Direct Injection Diesel Engine Running on Blends of Pongamia Pinnata Linn Oil (Honge oil) and Diesel Fuel, *Agricultural Engineering international, The CIGRE journal* **XI** 1316-1323.
[19] Jain Shashi Kumar., Kumar Sunil., Chaube Alok., 2011 Technical Sustainability of Bio diesel and Its Blends with Diesel in C.I. Engines: A Review, *International Journal of Chemical Engineering and Applications* **02** 324 – 328.
[20] Haldar S.K., Ghosh B.B., Nag A., 2009 Utilization of unattended Putranjiva roxburghii non-edible oil as fuel in diesel engine, *Renewable Energy* **34** 343–347.
[21] Chuaha. L. F. et. al., 2016 Waste Cooking Oil Biodiesel via Hydrodynamic Cavitation on a Diesel Engine Performance and Greenhouse Gas Footprint Reduction, *Chemical Engineering Transactions* **50** 301-306.
[22] Atmanli Alpaslan, 2016 Comparative analyses of diesel–waste oil biodiesel and propanol, n-butanol or 1-pentanol blends in a diesel engine, *Fuel* **176** 209-215.
[23] Lingfa. P et. al., 2015 Performance and Emission Characteristics of a Diesel Engine run by Blend of Nahar and Waste Cooking Oil Methyl Ester, *IJIRST* **01** 2349-6010.
[24] Murugesan A. et.al., 2009 Bio-diesel as an alternative fuel for diesel engines—A review, *Renewable and Sustainable Energy Reviews* **13** 653–662.