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Research Article

Experimental Analysis of Emission Characteristics of Direct Injection CI Engine using FOME and its Diesel Blends as Bio-Fuel

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Abstract

In recent times, several developing countries have significantly focused their research on for renewable fuels in order to save the fossil fuel for the future generations. The methyl esters of edible and non-edible oils are predominantly distinguished alternative fuels because of their low emission characteristics and environmental friendliness. Currently the research has been shifted towards animal fat oils and this paper is aimed at evaluating the emission characteristics of fish oil methyl ester (FOME) and their diesel blends as bio-fuel. Methyl Ester of Fish Oil (FOME) was derived through transesterification process and to achieve the intended objective, an experimental investigation was carried-out using single cylinder, 4-stroke water cooled direct injection compressive injection engine fueled with FOME and different blends (BF20, BF40, BF60 and BF100) of FOME in comparison to diesel. The experiment results reveals that BF100 has lower CO emission, lower smoke density, lower particle pollution and relatively higher NO_x emission values when compared to Diesel.

Keywords: *Bio-diesel, Emission Characteristics,Methyl Ester, AnimalFats, Transesterification.*

1. Introduction

Increase in the demand for fuel, the dearth of fossil fuel reserves will make renewable energy resources more captivating and researchers are forced to focus research on alternative fuels. The literature reveals that the most feasible way to meet this growing demand is by utilizing bio-diesels as alternative fuels. Bio-diesel is the most significant and indispensable form of fuel that can be used directly in any existing, unmodified diesel engine. Moreover the biodiesels are more environmental friendly than gasoline and petroleum diesels.The biodiesel or its blend with diesel can be used as a fuel, directly.

Biodiesel production in rural areas in the developing countries can impact tremendously with respect to fiscal growth as well as job creation. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and reduction in dependence on imported crude oil and reduction in air pollution(Deepak, *et al.,*2008).The bio-diesel that was produced at the rural area can be used at the same production locality for their agricultural equipment operational purpose such as to operate the agricultural machines, pumps and other equipment which is eventually creates renewable energy and saves lot of conventional energy.

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Even though biodiesel has many advantages over diesel, the high cost of production is the main hurdle to its commercial application. The cost for making biodiesel is primarily the cost of feedstocks.

Currently, edible oils are most commonly used in the production of biodiesels and have a remarkable contribution in the preparation of alternative fuels. Edible oils like soybean, sunflower, rapeseed and palm are used as main biodiesel feedstocks throughout the world (Ivanav B. Bankovi´ c-Ili ´c*et al*., 2012). While the concern over usage of edible oils in the production of bio-diesel has also increased and greater than before because they compete with food products. In the recent years, due to less production of vegetable oils and exceptional usage in the food products causing to give a justifiable reason for utilization of these oils for bio-fuel production purposes. On the other side, non-edible oils are not used in any food products and most of the oils such as pongamia, jatrophacurcas has poisonous and toxic chemical compounds. Furthermore they could grow in the uncultivable waste lands. Due to this, interestingly the focus of researcher has been moved towards non-edible oils and endorsing that it would be promising feedstocks for the production of alternative fuel, especially in the developing nations like India where the demand for edible oils is more and hard to find excess amount of oil in huge quantities. In addition to that the environmental specialists are giving warning that the growing of these plants reduces concentrations of CO_2 in the atmosphere (Karmakar, *et* *al*., 2010) and the production cost is more than diesel because it is required to reduce high free fatty acids (FFAs) content in non-edible oils.

Livestock fats such as beef, porkand chicken fats can also be used to produce bio-fuels by trans-esterifying the fat with methanol/ethanol alcohol and a catalyst. Animal fats are very less expensive and it has high cetane number, high viscosity and typically in solid form at ambient temperature because of high saturated fatty acids content. High cetane number will help the engine for quick start and run noiselessly. But the fuel with high viscosity will lead to underprivileged atomization and result in incomplete combustion. To make animal fats usable as bio-diesel, trans-esterification process will be adopted in gentle mild conditions. The saturated fatty acids have naturally high cetane number and values 60 or more are common. Edible oils such as Soybean-oil based biodiesel usually have cetane number of about 48 - 52 and petroleum-based diesel fuel is usually 40 - 44. When animal fat biodiesel is blended with diesel, high cetane number will be yielded that will help the engine start instantly which overcomes the general problem of usage of edible oils as bio-diesels. Animal tallow generated biodiesel offers a wide range of energy, environmental and economic advantage (Nelson*et al.*, 2006). Biodiesel produced from animal fats is being used in USA and in many European countries to reduce particle pollution and to moderate the reliance on petro-diesel fuel.

Even though the research on bio-diesels has started in the nineteenth century, but the research topic is still fascinating across the globe. According to the history of biodiesel fuel, Rudolf Diesel's prime model ran on its own power for the first time in Germany in 1893.Vegetable oil as bio-diesel in diesel engine and researchers observed considerable improvement in the engine performance and substantial reduction in the exhaust smoke opacity when compared with diesel as fuel (Agarwal, *et al.,*2008).Modi*et al*., evaluated the performance and exhaust emissions of twin cylinder water-cooled diesel engine using blends of diesel and palm biodiesel as the fuel. The results shown that bio-diesels have low brake thermal efficiency, lower smoke, SO2, lower PM (particulate matter) and lower CO with some increase in emission of oxides of nitrogen and the exhaust gas temperature increased with raise in power and amount of biodiesel(Modi, *et al.,*2010). Hwanam Kim *et al*., studies the exhaust gas characteristics and particulate matter on a CRDI diesel engine using diesel, biodiesel and ethanol blends and unveiled the reduced CO, HC, smoke emissions and total number of particles emitted, but increased NO_x emissions when biodiesel and ethanol blends used (Hwanam*et al*., 2010). Pramanik*et al*., investigated the performance of engine using the JatrophaCurcus blends as bio-fuel and their research identified the considerable improvement in the engine performance compared to neat vegetable oil. The exhaust gas temperature and specific fuel consumption were decreased and emission characteristics were closer todiesel (Pramanik*et al*., 2003).HadiRahimi, *et al*., were carried-out an experiment on the diesel oil, sunflower methyl ester and ethanol and the research results revealed that power and torque generated by the diesel engine using diesel-ethanol-biodiesel blends and diesel were found to be very comparable. The CO and Hydro Carbon emission concentration of diesel-ethanol-biodiesel blends decreased when compared to diesel fuel and diesel– biodiesel blends (HadiRahimi, *et al*., 2009).Goering *et al*., investigated the characteristics of 11 vegetable oils to find the best-fit alternative fuel source and found that corn, cottonseed, sesame, rapeseed, and soyabean oils had the most favorable fuel properties (Goering *et al*.,1982) . RecepAltin*et al*., the studied exhaust emissions and engine performance of a diesel engine using refined sunflower oil, cottonseed oil, soybean oil and their methyl esters . Modest power loss, higher particulate emissions and less NO_x emissions with neat vegetable oils better performance than diesel was identified (Altin*et al*., 2001).Barabas*et al*.,investigated the properties, performance and emissions of the diesel, biodiesel and ethanol blends and compared with diesel fuel. Investigations revealedthat considerable performances decrease, especially at low engine loads. Significant CO emissions decrease due to an increase of CO_2 emissions (Barabas*et al*., 2010). Kaligeros*et al*., were carried-out experiments on a single cylinder diesel engine using sunflower oil and olive oil as fuels in different proportions with marine diesel. They found lower unburned hydrocarbon, carbon monoxide, particulate matter and NO_x emissions with blends than 100% vegetable oils (Kaligeros*et al*., 2003). Metin Guru *et al*.,were used chicken fat biodiesel with synthetic Mg additive in a single cylinder, DI diesel engine and studied performance and exhaust emissions of the engine. The study results revealed that there is no significant change in engine torque, increase in fuel consumption due to the lower heating value of biodiesel, decrease in CO and smoke emissions, but NO_x emission increased by 5% (Guru *et al*.,2010).

2. Objective of the Study

The objective of the present study is to evaluate the emission characteristics of a single cylinder, 4-stroke water cooled DI diesel engine using diesel, fish oil methyl ester (FOME) and their diesel blends.

3. Transesterification

Transesterification process is the reaction of a triglyceride (fat/oil) with alcohol in the presence of a catalyst will produce the methyl esters or biodiesel and glycerin. The characteristics of the fat are ascertained by nature of fatty acids appended to the glycerin and acids can have an effect on the biodiesel characteristics. The tri-glyceride will react with ethyl or methyl alcohol in the presence of a catalyst, usually an alkaline such as sodium hydroxide. Virtually all biodiesel is produced using catalyzed trans-esterification as it is the most economical process requiring only low temperatures and pressures and producing a highest yield.

4. Experimental Setup

Experimental investigation was carried out with single cylinder 4-stroke water cooled direct injection CI engine. The engine was connected to eddy current dynamometer and experimental setup was illustrated in Fig 1.

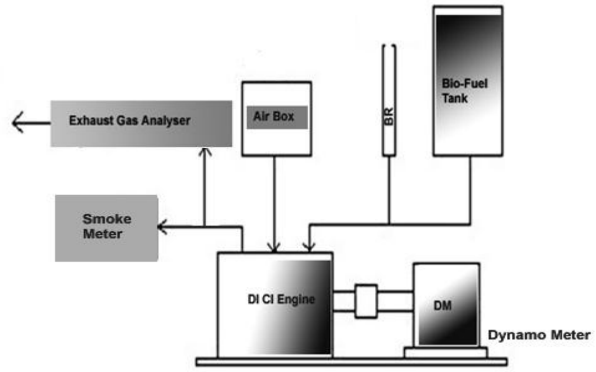

Fig 1: Schematic Diagram of Experimental Setup

AVL 437smoke meter was used to measure the smoke density of the exhaust from the diesel engine and exhaust gas analyzer was used for the measurement of CO and NO_x emissions. The specifications of the diesel engine are given below in Table 1.

Table 1: Engine Specifications

Type	Kirloskar
Details	Single cylinder, Four stroke, DI, Water cooled
Bore & Stroke	87.5 × 110 mm
Rated Power	3.7 KW at 1500 rpm
Compression ratio	17.5 :1
Speed	1500 rpm
Peak Pressure	77.5 kg/cm²

The engine was operated on diesel first and then on methyl esters of fish oil and their blends. Series of emission tests were conducted with different blends on the engine and recorded the readings. The data obtained from the tests were then analyzed using bar and radar graphs regarding emission characteristics of all bio-diesels and diesel.

5. Results and Discussion

5.1 CO Emission

The Figure 2illustrates the CO emission variation with respect to the load for Diesel and FOME blends at constant speed of the engine. The CO emission is decreasing with the increasing of FOME percentage. Around 2/3 of reduction in CO emission of neat FOME compared to Diesel was observed and for every 20% addition of FOME in the Blend, the CO emission is reduced by an average of 25-26%.

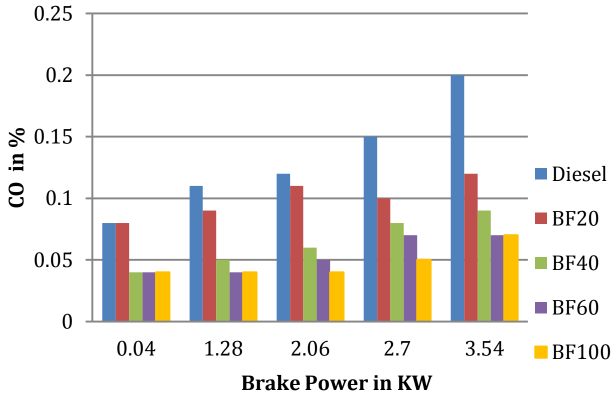

Fig 2: Brake Power vs. CO Emission

As shown in Fig 3, the graph is clearly revealing that the 100% FOME has low CO emission values and diesel has highest among all the FOME blends.

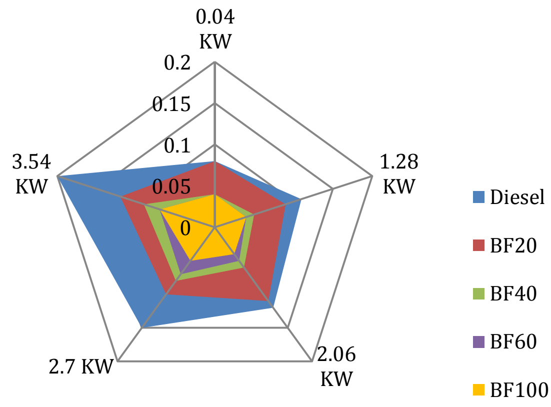

Fig 3: Brake Power and CO Emission

5.2 Smoke Density

Figure 4 shows variation of smoke density with brake power for diesel and FOME blends at constant speed of the engine. It is observed that smoke density is increasing with the increasing of brake power for all blends and decreasing with the increasing of FOME percentage. The smoke density has decreased an average of 18.3% of neat FOME when compared with diesel and reduced by approximately 5% for every 20% addition of FOME bio-diesel.

The graph shown in Fig 5 is prominently showing that the BF100 has very low smoke density and diesel has highest among all the FOME blends. The many researchers and literature review is establishing that biodiesel gives less smoke density compared to petroleum diesel.

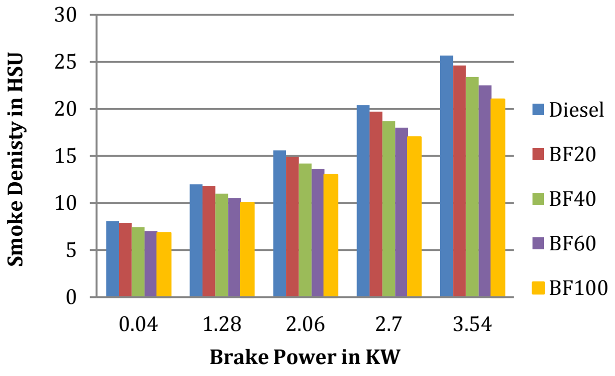

Fig 4: Brake Power vs. Smoke Density

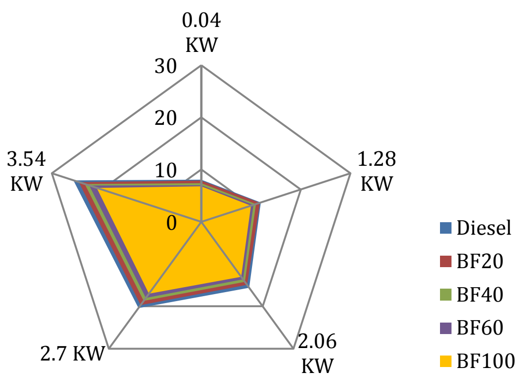

Fig 5: Brake Power and Smoke Density

5.3 Particle Pollution

Figure 6 shows particle pollution variation with brake power for diesel and FOME blends at constant speed of the engine. The particle pollution is increasing with the increasing of brake power for diesel and all blends but decreasing with the increasing of FOME percentage. The particle pollution is decreasing by about an average of 10% of neat FOME when compared with neat Diesel and reduced by around 4%for every 20% addition of FOME in the blend.

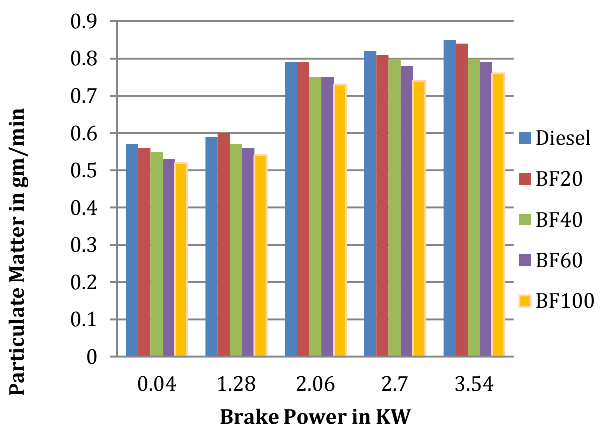

Fig 6: Brake Power vs. Particle Pollution

As shown in Fig 7, the graph is presenting that the particle pollution of neat FOME is very low compared to diesel and diesel has highest among all the FOME blends.

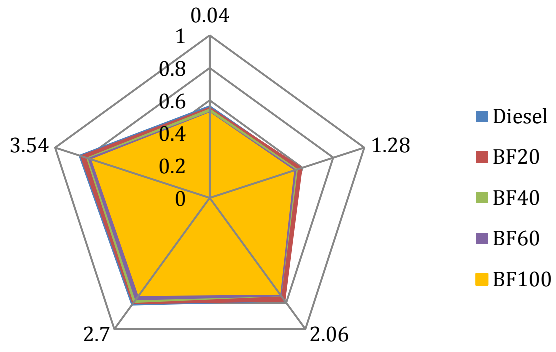

Fig 7: Brake Power and Particle Pollution

5.4 Oxides of Nitrogen (NO_x) Emission

Figure 8 illustrates oxides of nitrogen emission (NO_x) variation with brake power for diesel, FOME blends at constant speed of the engine. It is observed that NO_x emission is increasing with the increasing in brake power for all fuels at constant speed of the engine and increasing with the increasing of FOME percentage. At part load conditions the variation of NO_x emission of both biodiesel and diesel are indistinguishable, but at medium and full load conditions NO_x emission of FOME are distinct and neat FOME has higher values than diesel and their blends. The NO_x emission has decreased by an average of 25% of neat FOME bio-diesel when compared with diesel and increased by an average of 6% for every 20% addition of FOME in the blend.

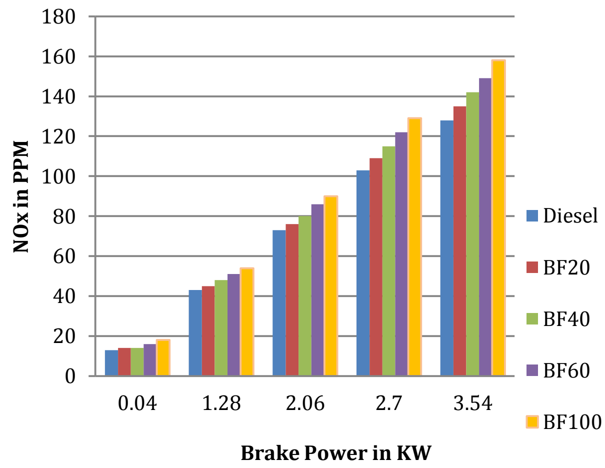

Fig 8: Brake Power vs. NO_x Emission

The graph shown in Fig 5 is focusing that the 100% FOME has very high NO_x values and diesel has lowest among all the FOME blends. BF20 has the lowest NO_x emission among the all FOME blends.

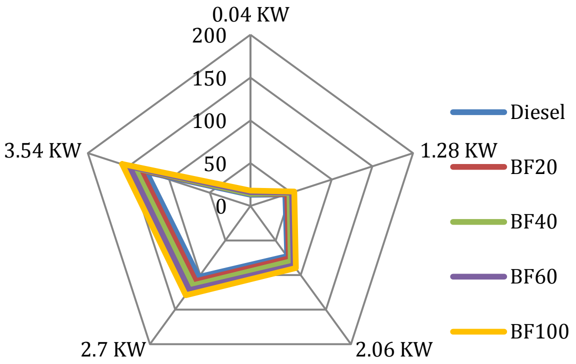

Fig 9: Brake Power and NO_x Emission

Conclusions

Bio-Diesel made with fish oil is new option that can be used as bio-diesel instead of edible and non-edible oils. The experimental results of Single cylinder, 4-stroke water cooled direct injection compressive injection engine fueled with FOME and different blends (BF20, BF40, BF60 and BF100) of FOME are clearly revealing that neat FOME bio-diesel has the following emission characteristics when compared to Diesel:

- *lower CO emission*
- *lower smoke density*
- *lower particle pollution and*
- *higher NO_x emission values*

In general bio-diesels are oxygenated fuels which lead to better fuel combustion that causes less CO emission. The formation of smoke is primarily resulted from the incomplete burning of the hydrocarbon fuel and partially reacted carbon content in the liquid fuel. The smoke density of FOME bio-diesel is less because of improved combustion characteristics of bio-diesel. Bio-diesel that are made with methyl esters are oxygenated fuel and it promotes the better combustion that causes reduction in particle pollution emission. Methyl esters with their lower stoichiometric air-fuel ratio relative to diesel can burn with less air requirement for combustion. This upshot higher NO_x emission and increases with increase in percentage of methyl esters in the FOME blends.

References

Ivana B. Bankovi´ c-Ili ´c,Olivera S. Stamenkovi´c,Vlada B. Veljkovi´, (2012), Biodiesel production from non-edible plant oils, Elsevier- Renewable and Sustainable Energy Reviews - 16 (2012) 3621– 3647

Deepak Agarwal, Lokesh Kumar, Avinash Kumar Agarwal, (2008), Performance Evaluation of a Vegetable oil fuelled CI Engine, Renewable Energy, Volume 33, Issue 6, June 2008, Pages 1147–1156

Karmakar A, Karmakar S, Mukherjee S. (2010), Properties of various plants and animals feedstocks for biodiesel production. BioresourTechnol 2010;101:7201–10.

Nelson RG, Schrock MD. (2006), Energetic and economic feasibility associated with the production, processing and conversion of beef tallow to a substitute diesel fuel. Biomass Bioenergy 2006; 30: 584-91.

Agarwal, D.; Kumar, L.; Agarwal, A.K., (2008), Performance evaluation of a vegetable oil fuelled compression ignition engine.Rewable Energy 33, 2008, 1147-1156.

Modi, A.J., Gosai, D.C. (2010). Experimental study on thermal barrier coated diesel engine performance with blends of diesel and palm bio-diesel. SAE International Journal of Fuels and Lubricants, ISSN: 1946-3960, 3 (2), 246-259

Hwanam Kim, Byungchul Choi, “The effect of biodiesel and bioethanol blended diesel fuel on nanoparticles and exhaust emissions from CRDI diesel engine” Renewable energy, 35, 2010, pp. 157–163.

Hadirahimi, Barat Ghobadian, TalalYusaf, GholamhasanNajafi, Mahdi Khatamifar, “Diesterol: An environment-friendly IC engine fuel”, Renewable Energy, 34, 2009, pp. 335–342.

C.E. Goering, A.W. Schwab et al., Fuel Properties of Eleven Vegetable Oils, Trans. ASAE, 25 (4-6), 1982, 1472-1477.

Kaligeros, S., Zannikos, F., Stournas, S., Lois, E., Anastopoulosd, G.,TeasCh and Sakellaropoulos, F. (2003). AnInvestigation of Using Bio diesel/Marine Diesel blends on the Performance of a Stationary Diesel Engine, Journal ofBiomass and Bio energy, No.24, pp. 141-149.

Sahoo P.K., Das. L.M, Babu.M.K.G and Naik.S.N., Biodiesel development from high acid value polanga seed oil and performance evaluation in a CI engine, Fuel, 86, 2007, 448-454.

Metin Guru, AtillaKoca, Ozer Can, Can Cinar, FatihSahin, ―Biodiesel production from waste chicken fat based sources and evaluation with Mg based additive in a diesel engine, Renewable Energy 35 (2010), 637-643.