PERFORMANCE AND EMISSION CHARACTERISTICS OF A DIESEL ENGINE FUELED WITH RICE BRAN OIL METHYL ESTER BLENDS

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Abstract: *The backbone of the economy of a nation is dependant of surface transport. Thus diesel engines play a vital role as prime movers. The recent energy trend offers a challenge as well as an opportunity to look for substitutes of fossil fuels for both economic and environmental benefits. Investigation and development of bio-fuels as an alternative and renewable source of energy for transportation has become a major target in the effort towards energy self-reliance. Bio-fuel commands crucial advantages such as technical feasibility of blending, superiority from the environment and emission reduction angle, its capacity to provide energy security to remote and rural areas and employment generation. Moreover, Bio fuel will also provide rich bio mass and nutrients to the soil. This paper presents the results of performance and emission analyses carried out in an unmodified diesel engine fueled with rice bran oil methyl ester (biodiesel) blends with diesel. Engine tests have been conducted to get the comparative measures of brake thermal efficiency, specific fuel consumption and emissions such as CO, HC, NOx to evaluate the behavior of biodiesel and diesel in varying proportions. The results reveal that blends of rice bran methyl ester with diesel up to 20% by volume (20BD) provide better engine performance and improved emission characteristics.*

Keywords: *Diesel, rice bran oil, methyl esters, emissions.*

NOTATIONS

RBO	- Rice bran oil
100D	- 100% diesel
BD	- Biodiesel
10 BD	- 10% biodiesel and 90%diesel
20 BD	- 20% biodiesel and 80%diesel
30 BD	- 30% biodiesel and 70%diesel
40 BD	- 40% biodiesel and 60%diesel
50 BD	- 50% biodiesel and 50%diesel
BTE	- Brake thermal efficiency
EGT	- Exhaust gas temperature
CO	- Carbon monoxide
HC	- Unburned hydrocarbon
NOx	- Oxides of nitrogen

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1. Introduction

Diesel engines have a vital role particularly for transportation systems. The exhaust emissions from diesel engines fueled with commercial diesel fuel have caused air pollution and global problems. There is a general agreement that biodiesel and its blends with diesel fuel provide a substantial reduction in HC, CO and smoke emissions with slight performance loss in the diesel engine [1-4].

Many researchers [5-10] have studied the potentiality of vegetable oil based fuels as an alternate fuel for compression ignition engines. Pyror et al [11] have conducted short and long term engine performance tests using 100% soybean oil in a small diesel engine. It has been reported that the short-term test with soybean oil indicated the performance similar to that of diesel fuel and long-term engine testing could not be carried out due to power loss and carbon buildup problem on the fuel injectors. Seppo A. Niemi et al [12] have tested a turbo charged 4 cylinder direct injection diesel engine using mustard oil. It has been reported that the engine developed power which is equal to that of diesel. It has been further stated that the smoke and NOx emissions were lower than diesel. Sivakumar et al [13] have experimented in a single cylinder four stroke diesel engine using neat and transesterified cotton seed oil and reported that the CO, particulate matter and smoke emissions were reduced and NOx emission was slightly increased.

There are many plant species which bear seeds rich in oil. Of these some promising species produce oils like karanja, jatropha, palm, sal, rice bran, neem, etc have great potential to make biodiesel for supplementing other conventional sources like fossil fuels [14]. In this analysis, the rice bran oil (RBO) is chosen as a potential alternative for producing biodiesel and use as fuel in compression ignition engines.

Rice bran oil, a renewable vegetable oil, is extracted from rice bran, which is a by-product of the rice milling process. During this process, rice bran is separated from paddy to produce rice. Since rice is the staple food for most of the world, the availability of rice bran for oil extraction is renewable in nature. Global production of rice (paddy) was ca. 604 million tonnes (Mt) in 2004, which would yield 7.25 Mt of rice bran oil (RBO) annually [15]. Asian countries produce more than 60% of the global rice production. In this scenario, India ranking second in rice production has the capacity to yield nearly 1 Mt of RBO [15]. Rice bran oil has the potential to replace almost 0.9% of the world diesel consumption.

2. Experimental Process, Setup and Procedure

The process used to reduce the viscosity of the rice bran oil is transesterfication process. Transesterification is the chemical reaction between triglycerides and alcohol in the presence of a catalyst to produce monoesters. The long and branched chain triglyceride molecules are transformed to monoesters and glycerin. Transesterification process consists of a sequence of three consecutive reactions where triglycerides are converted to diglycerides; diglycerides are converted to monoglycerides followed by the conversion of monoglycerides to glycerol. In each step an ester is produced and thus three ester molecules are produced from one molecule of triglyceride [16, 17]. The properties of these esters are comparable to that of diesel.

Table 1: Properties of Biodiesel

Properties	Diesel	Biodiesel
Calorific value (kJ/kg)	42400	38984
Specific gravity	0.822	0.889
Viscosity at 40°C (c-s)	3.72	5.3
Flash point (°C)	62	97
Acid number (mg KOH /g)	-	0.46
Distillation temperature (°C)	337	352

Transesterification of rice bran oil was carried out by heating of oil, addition of NaOH and methyl alcohol, stirring of mixture, separation of glycerol, washing with distilled water and heating for removal of water [18-20]. The properties of rice bran oil methyl ester (biodiesel) prepared by the transesterification process were compared with diesel in Table 1.

The CI engine in this experiment was vertical, single cylinder, four stroke, water cooled direct injection diesel engine coupled with an electrical alternator. Thermocouples are used for measuring exhaust gas temperature and cooling water temperatures. Exhaust gas analyzer was used to measure CO, HC and NOx emissions. The experimental setup is shown in fig.1. Testing was carried out at a constant speed rate of 1500 rpm, at no load condition to full load condition for all the test fuel. The engine was first operated on diesel fuel and then with blends of biodiesel. The fuel consumption rate, air consumption rate, coolant consumption, coolant temperature and composition of exhaust gases were recorded for 5 different loads at steady state condition.

3. Results and Discussions

The comparison of brake thermal efficiency (BTE) with different load conditions is shown in fig 2.The graphs show similar trend from no load to full loads of operation for all test fuels. At high load, diesel fuel shows an efficiency of 7.74% and 12.6% higher than 20RBME and 50RBME respectively. At medium loads, Diesel has efficiency 10.4% higher than 20RRME whereas 50RRME has 15.6% lesser than efficiency of 100Diesel.The trend indicates that the BTE drops with the increasing RBME blend. This is due to poor spray injection pattern and further no effective utilization of air resulting incomplete combustion

4. Test Procedure

Testing was carried out at a constant speed rate of 1500 rpm, at no load condition to full load condition for all the test fuel. The engine was first operated on diesel fuel and then with blends of biodiesel. The fuel consumption rate, air consumption rate, composition of exhaust gases were recorded for 5 different loads at steady state condition.

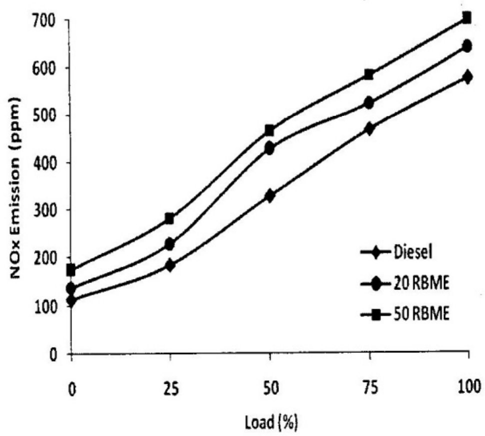

Fig. 6: NOx vs. Load

5. Results and Discussions

It was observed that, while operating the engine with blends of rice bran oil methyl ester, it was running smooth at all loads. The performance and emission characteristics for different percentages of load for diesel oil and biodiesel blends are given below.

The comparison of brake thermal efficiency (BTE) with different load conditions is shown in Fig 2. At high load, diesel fuel has an efficiency of 8% higher than biodiesel blends. Also 50BD has efficiency, 1% lesser than 100Diesel. At medium loads, 100Diesel has efficiency 3% higher than 30BD whereas 20BD and 50BD has 6% **lesser** than efficiency of 100Diesel.This is due to poor spray character and no effective utilization of air resulting incomplete combustion.

The comparison of exhaust gas temperature (EGT) for all the test fuels at different load conditions is shown in fig 3. The EGT graphs show a similar trend throughout the operation. The results show that the exhaust gas temperature increases with load in all case. If any fuel shows higher EGT indicates a slow burning or delayed combustion. The exhaust gas temperature was higher for 50RBME fuel indicates the prolonged after burning phase. At higher load the exhaust temperature of 20RBME and 50RBME is 7.84% and 13.5% higher than Diesel fuel.

The figure 4 shows the emission of CO for all fuels at all loads. The CO emissions for all the test fuels at different loads are almost similar. Emissions of CO from a diesel engine are mainly due to the physical and chemical properties. The main difference in ester based fuel compared to diesel is the oxygen content and Cetane number. At higher load CO content of Diesel has 2.45% and 9.75% lesser than 20RBME and 50RBME respectively. The more the emission of CO and HC indicates normally the poor combustion. If any fuels take part well in combustion the CO and HC emission would be lower. There are many factors to claim such as fuel composition, fuel properties fuel injection, spray and air entrainment.

The variations of unburned hydrocarbon with load for base diesel and biodiesel blends are shown in fig 5. Here, the HC emissions of biodiesel and its blends are lower than the neat-diesel operation. At higher loads, HC content of Diesel has 10.28%, and 17.6% higher than 20RBME and 50RBME respectively.

The emission of NOx indicates the combustion pattern. The NOx is formed in the engine exhaust are a combination of nitric oxide and nitrogen oxide. When nitrogen and oxygen react at relatively at high temperature. The NOx formation is mainly from the nitrogen present in air and also from fuel combine with oxygen at peak flames. The comparison of NOx emissions with different loads are shown in fig 6. The trend depicts here clearly says that the increase in NOx emission incase of esters gradually increases from no load condition to maximum load. At maximum load, the 20RBME and 50RBME blends produce 10.17% and 17.41% higher NOx emission than Diesel fuel operation.

6. Conclusions

Biodiesel from rice bran oil is a promising alternative for using in diesel engines. It is easier for delivering and storing than diesel fuel,

because of its higher flash point. The lower concentrations of biodiesel blends found to improve the thermal efficiency. CO, NOx and HC emissions are low in all biodiesel blends when compared to pure conventional diesel.

References

[1] Ozsezen A.N, Canakci M, "The emission analysis of an IDI diesel engine fueled with methyl ester of waste frying oil and its blends", Biomass and Bio energy, Vol.34, 2010, pp.1870-1878.

[2] Lin Y, Wu Y.G, Chang C.T, "Combustion characteristics of waste oil produced biodiesel/diesel blends", Fuel, Vol.86, 2007, pp.1772-1780.

[3] Canakci M, Van Gerpen J.H, "Comparison of engine performance and emissions for petroleum diesel fuel, yellow grease biodiesel and soyabean oil biodiesel", Trans ASAE, Vol.46, 2003pp.937-944.

[4] Deepanraj B, Dhanesh C, Senthil R, Kannan M, Santhoshkumar A, Lawrence P, "Use of palm oil biodiesel blends as fuel for compression ignition engines", American Journal of Applied Sciences, Vol.8, 2011, pp.1154-1158.

[5] Purushothaman K, Nagarajan G, "The effect of Orange oil-diesel fuel blends on direct injection diesel engine performance exhaust emissions and combustion", Thammasat International Journal of Science and Technology, Vol.13, 2008, pp.38-47.

[6] [6] Ramadoss AS, Jayaraj S, Muraleedharan C., "Charactrerixation and effect of using rubber seed oil as fuel in the compression ignition engines", Renewable Energy, Vol.30, 2005, pp.795–803.

[7] Sukumar Puhan, Vedaraman N, Rambrahamam BV, Nagarajan G, "Mahua (Madhuca indica) seed oil: A source of renewable energy in India", Journal of Scientific and Industrial Research, Vol.64, 2005, pp.890-896.

[8] Ramadhas, A. S., Muraleedharan, C., Jayaraj, S., 2005, "Performance and emission evaluation of a diesel engine fueled with methyl esters of rubber seed oil", Renewable Energy, 30, pp. 1789-1800.

[9] Deepanraj B, Nadanakumar V, Senthil R, Lawrence P, "Experimental Evaluation of Diesel Engine Performance and Emission using Blends of Mahua Oil Methyl Ester and Diesel Fuel", National Conference on Contemporary Approaches in Mechanical Engineering (NCCAME'12), Karpaga Vinayaka College of Engineering, February 29, 2012, pp.24-27.

[10] Sharma, Y. C., Singh, B., Upadhyay, S. N., 2008, "Advancements in development and characterization of biodiesel: A review", Fuel, 87, pp. 2355–2373.

[11] Pryor RW., Hanna MA., Schinstock and Bashford LL., "Soybean oil fuel in a small diesel engine", Transactions of the ASAE, Vol.26, 1983, pp. 333-337.

[12] Seppo A. Niemi, Petri E. Illikainen, Mika LK. Makinen and Vaino OK, Laiho, "Performance and exhaust emissions of a tractor engine using mustard seed oil as fuel", SAE paper No. 970219, 1997, pp.21-32.

[13] Siva Kumar A, Maheswar D, Vijaya Kumar Reddy K, "Comparison of Diesel engine performance and emissions from neat and transesterified Cotton seed oil", Jordan Journal of Mechanical and Industrial Engineering, Vol.3, 2009, pp.190-197.

[14] Karaosmanoplu F, "Vegetable oil fuels: A review", Energy Sources, Vol.70, 1999, pp.221-231.

[15] Saravanan S, Nagarajan G, Lakshmi Narayana Rao G, Sampath S, "Feasibility study of crude rice bran oil as a diesel substitute in a DI-CI engine without modifications", Energy for Sustainable Development, Vol.11, 2007, pp.83 – 92.

[16] Duraisamy M.K, Balusamy T, Senthilkumar T, "Experimental Investigation on A Mixed Biodiesel Fueled Direct Injection Diesel Engine", International Journal of Applied Engineering Research, Vol.5, 2010, pp.253-260.

[17] Ayhan Demirbas, "Biodiesel production from vegetable oils via catalytic and non-catalytic supercritical methanol transesterification methods", Progress in Energy and Combustion Science, Vol.31, 2005, pp. 466–487.

[18] Naik S.N, Vidya Sagar D, Mether L.C, "Technical aspects of biodiesel production by transesterification-A review", Renewable and Sustainable Energy Reviews, Vol.10, 2006, pp.248-268.

[19] Hidekl Fukuda, Akihiko Kondo, Hideo Noda, "Biodiesel fuel production by transesterification of oils", Journal of Bioscience and Bioengineering, Vol.92, 2001, pp.405-416.

[20] Fangrui M.A., Hanna M.A, "Biodiesel production: A review", Bio Resource Technology, Vol. 70, 1999, pp.1-15.

[21] Deepanraj B, Sankaranarayanan G, Dhanesh C, Lawrence P, "Performance test of IC engine using diesel-palm oil methyl ester blends", National Conference on Emerging Research and Advances in Mechanical Engineering (ERA 2011), Velammal Engineering College Chennai, March 23, 2011, pp.241-244.

[22] Ganesan V, Internal Combustion Engineering. Tata McGraw-Hill Publishing Company Limited, New Delhi, 2003.

[23] Mathur M.L, Sharma R.P, Internal Combustion Engineering. Dhanpat Rai Publications (P) Limited, New Delhi, 2000.

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