EMISSION AND PERFORMANCE INVESTIGATION of RAPESEED METHYL ESTER AND DIESEL FUEL

ИССЛЕДОВАНИЕ ЭМИССИЙ И ЭКСПЛОТАЦИОННЫХ ХАРАКТЕРИСТИК МЕТИЛОВОГО ЕСТЕРА ИЗ РАПИЦЫ И ДИЗЕЛЬНОГО ТОПЛИВА

Dr. Alp Tekin ERGENÇ[1] Res. Asst. MSc. Orkun ÖZENER[1] Res. Asst. MSc. Levent YÜKSEK[1] Phd. Student Onur ACUR[1]
Yildiz Technical University İstanbul,TURKEY[1]

ABSTRACT

This study was focused on , the comparison of performance and emission output of a compression ignition (CI) engine when using Rapeseed Methyl Ester(RME) instead of conventional diesel fuel. The experiments were carried on with neat RME, which was produced via transesterification process and neat conventional diesel fuel. During the experiments, first the engine was operated at full load and variable engine speed conditions ,then the power and brake specific fuel consumption (BSFC) was measured. Then the emission tests were carried on 4,15 Bars of Brake Mean Effective Pressure (BMEP) at 3050 rpm engine speed which this condition was predefined from first stage of the experiments. Then the CO,CO_2 and NO_x values were measured for two fuel. Fuelling with RME resulted ~13% decrease at Brake Effective Power(BEP) and 9% increase on BSFC. The NO_x emissions were decreased 40% when fuelling with biodiesel while there were significant decrease was noted for CO and CO_2.

1. Introduction

Energy is the most valuable and indispensable requirement of modern life. Primary energy sources of the world such as petroleum are finite sources and from the early stages of the industrialisation total production of oil has increased.[1] The increasing energy consumption of world economy, has created a demand for sustainable and clean energy sources. This situation encouraged the scientists to search for alternative renewable and sustainable fuel instead of fossil based fuels. Internal combustion engines are the main energy conversion machines and have widespread use because of its' compact structure, high thermal efficiency and proved technology. Vegetable oils and derivatives are one of the alternative fuel that can be replaced with conventional diesel fuel considering to the internal combustion engines.

Vegetable oils have higher density, viscosity and volatility and have bigger molecular structure than diesel fuel[2], these different properties negatively affect injection and spray atomization of fuel in combustion chamber. Poor atomization of vegetable oils cause higher deposit formation on combustion chamber and injector nozzles that reduces engine operation period when compared to mineral diesel fuel.[3,4] Vegetable oils can be used as fuel with additional methods which are blending with mineral diesel, heating of oil for reducing viscosity and converting to fatty acid esters with applying transesterification. Fatty acid methyl esters (FAME) have similar properties when compared to petroleum diesel, thus implementation as fuel or additive can be feasible.[4]

Hemmerlein et. al. compared the performance and emission characteristic of rapeseed oil with diesel oil at several different engine types. Engines which invastigated in this study were covered the range from 40 to 274 kW power output. Torque and power output with rapeseed oil were only 2% lower than with Diesel fuel when lower heating value of rapeseed oil were 7% lower. Authors explained the situation with higher injected fuel quantity of rapeseed oil than with Diesel fuel depending on higher viscosity of rapeseed oil. Carbon monoxide emissions are within the whole engine operating range up to 100 % higher and hydrocarbon emissions identically rised with rapeseed oil compared to Diesel fuel. Emissions of nitrogen oxides were up to 25 % lower with rapeseed oil. Authors related results with slower combustion and lower maximum temperature in the combustion chamber.

FAME have similar fuel properties with Diesel fuel, also it is biodegradable and renewable source of energy. FAME so called biodiesel also has higher viscosity, higher density and higher bulk modulus than diesel fuel[2,6], which expose quite different injection characteristics (injection pressure, injection timing, spray tip penetration, cone angle etc.)[7,8,9] than those of mineral Diesel fuels that leads to difference in tail pipe emissions, deposit formation and performance of the engine.[10]

When using biodiesel instead of diesel fuel in a compression ignition (CI) engine, most common and the significant effects on gaseous emissions and performance of engine are well studied by researchers[11,12,13,14]. Generally higher fuel consumption and lower power output obtained with biodiesel which it is related to biodiesel's lower heating value. Lapuerta et. al. pointed out the Nitric Oxide (NO_x) emissions are tends to increase because of advancing phenomenon of the injection start that originates from the physical properties of the biodiesel while the total hydrocarbon emissions are tends decrease because of the oxygen content of biodiesel. The general trend for Carbon monoxide (CO) emissions are towards to reduce because of oxygen enrichment that comes from the fuel, helps for a more complete combustion. At the other hand from the perspective of Carbon dioxide (CO_2) greenhouse gas, results are similar.

Labeckas et.al. investigated the effect of Rapeseed Methyl Ester (RME) and blends with diesel fuel on direct injection diesel engine performance and tail pipe emissions. Results of author's experiments indicate, Brake Specific Fuel Consumption (BSFC) of neat RME was 18% and 23% higher than diesel oil, also at fully opened rack position and low speed, the BSFC was lower by 3.2% and 1.7% for the B10 and B20 blends. At higher engine speeds, BSFC was lower by 3.5% for both the B5 and B10 blends, at rated power, the B5 blend suggests slightly better (1.5%) fuel economy.

A modern internal combustion engine has to met several demand which mandated by regulations and consumers. Environment pollution related to engines become a major problem thus harmful combustion products has to be reduced.

The purpose of this research was to investigate the effect of biodiesel on internal combustion engine performance, exhaust emissions. Several tests carried on a diesel engine and results summarized.

2.Materials and methods

2.1 Fuels

Test fuels are RME and No.2 Diesel fuel. Both type of fuels were used as neat form. RME fuel is represented as B100 and diesel fuel represented as D in graphics. Fuel properties are listed in table 1 and table 2.

Table 1 Specifications of Diesel fuel

Specification	Unit	Test method	Limit		Test results
			min	max	
Specific gravity 15°C	kg/m3	ASTM D 4052	820	860	838
Flash Point	°C	ASTM D 93	55		66
Water content	mg/kg	ASTM D 6304		200	98
Sulphur content	mg/kg	ASTM D 2622		7000	1471
Copper strip corrosion	3h, 50 °C	ASTM D 130	Class 1		1A
Cetan index	Calc.	ASTM D 4737	46		51,4
Viscosity 40°C	mm²/s	ASTM D 445	2.0	4,5	2,812
Cold filter plugging point	°C	IP309			-20

Table 2 Specifications of Rapeseed methyl ester

Specification	Unit	Test method	Limit		Test results
			min	ma x	
Specific gravity 15°C	kg/m3	EN ISO 3675	860	900	884
Flash Point	°C	EN ISO 2719	>101		>130
Water content	mg/kg	EN ISO 12937	-	500	480
Copper strip corrosion	3h, 50 °C	EN ISO 2160	Class 1		1A
Cetan index	Calc.	EN ISO 5165	51	-	55
Viscosity 40°C	mm²/s	EN ISO 3104	3,5	5	4,9
Acid value	mg KOH/g	EN 14104	-	0,5	0.42
Iodine value		EN 14111	-	120	102
FAME content	% (m/m)	EN 14103	96,5	-	97,2

2.2 Test bed and instruments

A single cylinder research engine was used for performance and emission tests. A hydrokinetic dynamometer was used for loading the engine. The engine speed was measured with infrared tachometer. The engine torque was measured with load cell. Fuel consumption was determined with volumetric method. The duration of 50 cm^3 of fuel consumption was measured, at predefined engine operating point. Air consumption of the engine was measured with an inclined manometer via standard orifice which was mounted inlet side of a air oscillation absorber tank. A Bilsa brand Mod 2210 model gas analyzer was used to determine CO, CO2, NO_x emissions. Oil temperature was measured with using thermocouple which mounted on oil pan drain screw. During the tests, first the engine was set to desired load and speed condition then the measurements were taken. Scheme of test bench shown in figure 1 and details of test engine are listed in table 3.

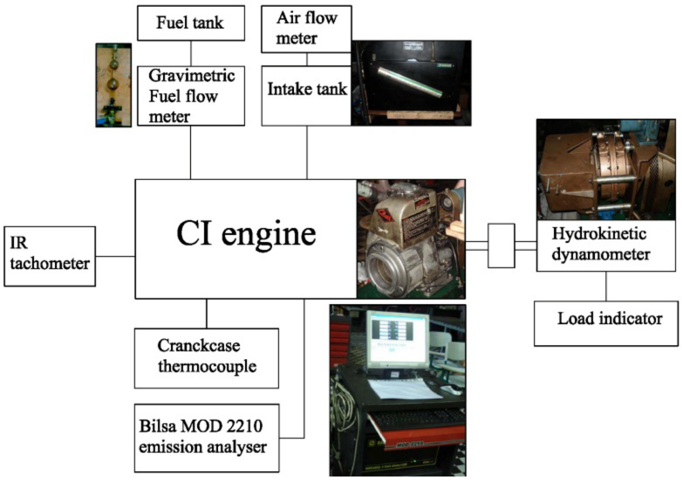

Figure 1- Schematic of test bench.

Table 3 Specifications of Engine Test Bed

Engine Manufacturer	Petter Diesel
Model-Type	AA1
Aspiration	Naturally aspirated
Number of cylinders	1
Cooling method	Air cooled
Combustion technology	Indirect injection-Turbulence chamber
Bore x Stroke (mm)	69,85x57,15
Cylinder volume (cm^3)	219
Compression ratio	17:1
Lubricating oil capacity (l)	1,9
Speed range Min-Max (rpm)	1500-3600
Fuel injection pressure (bar)	183
Fuel injection timing BTDC	33° CA
Rated power DIN ISO 3046 (kW)	2,5

2.3 Methodology

Several tests performed for determination of the effect of RME on engine performance and emissions. For measuring the brake power of test engine, fuel pump rack adjusted to maximum position and engine power were noted at 500 rpm speed intervals. Performance tests repeated ten times for each fuel and mean values taken into account for plotting the power curve of engine. Maintaining equal conditions is necessary for emission investigation, such as equal load at same engine speed or injecting an equal fuel quantity into cylinder. Because of the characteristic of in-line-pump system and governor speed limiter, it's impossible to inject equal quantity of fuel into cylinder for both type of fuels. RME has higher density and viscosity than diesel fuel, which these properties were the main reason of altering quantity of injected fuel per cycle. In order to obtain comparable results, equal load at equal speed comparison method was selected, load condition and engine speed determined as 4,15 Bars of Brake Mean Effective Pressure (BMEP) and 3050 rpm respectively. After setting engine to related test conditions, gaseous emissions were measured.

3. Results and discussion

3.1 Performance tests result

Results of brake power measurements for diesel fuel and RME are shown in figure 2. Brake effective power of RME was decreased 13% when compared to diesel fuel. Also maximum brake power speed of fuels are different, this can be related to different lower heating value and density of RME. [15]

According to figure 3 BSFC has increased when using RME as test fuel. Up to 3000 rpm of engine speed approximately 9% increase obtained for RME but BSFC values almost identical for higher engine speeds. Difference between BSFC increase and power decrease, indicates better combustion of biodiesel. Pump-line-nozzle fuel injection system delivers higher quantity of biodiesel at same conditions due to higher viscosity of fuel. In addition, the higher viscosity reduces leakages in the pump leading to an increase in the injection line pressure. Therefore, a quicker and earlier needle opening is observed when compared to diesel fuel. Higher injection pressure improves the efficiency of combustion also early injection provides longer time for fuel to burn completely.

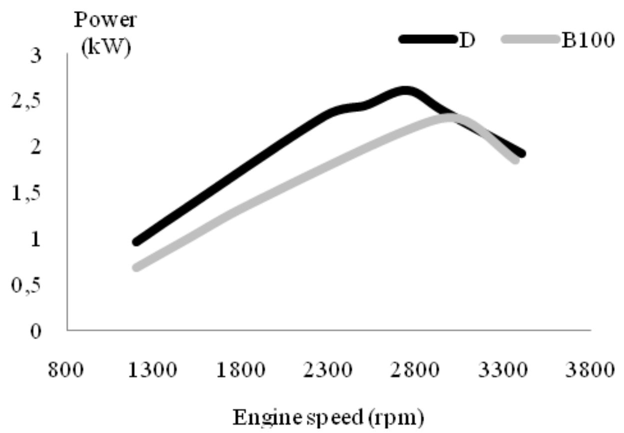

Figure 2. Brake Power as a function of engine speed.

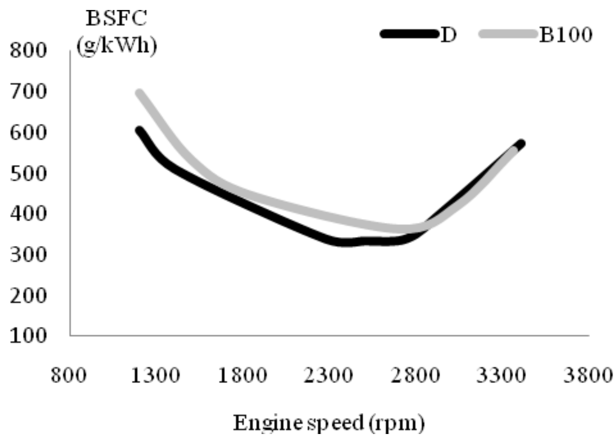

Figure 3. BSFC as a function of engine speed.

3.2 Emission test results

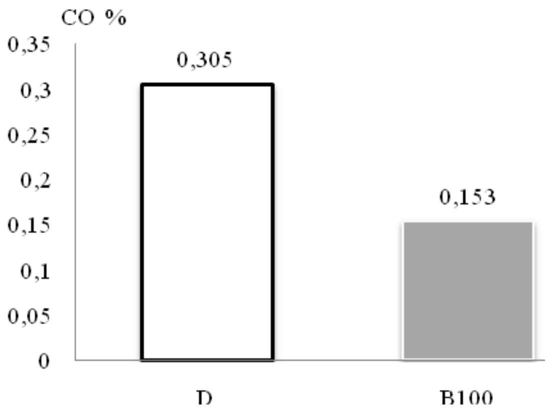

Figure 4. CO variation with respect to fuel type

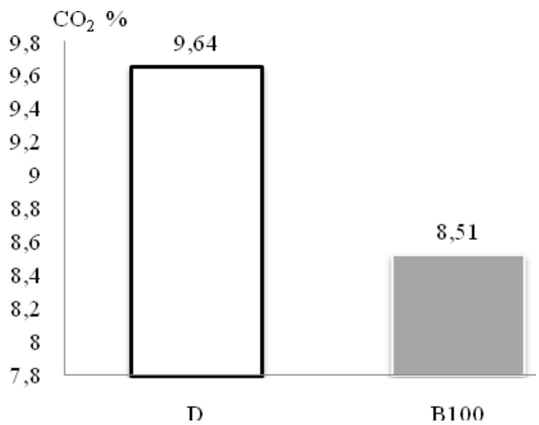

Figure 5. CO_2 variation with respect to fuel type

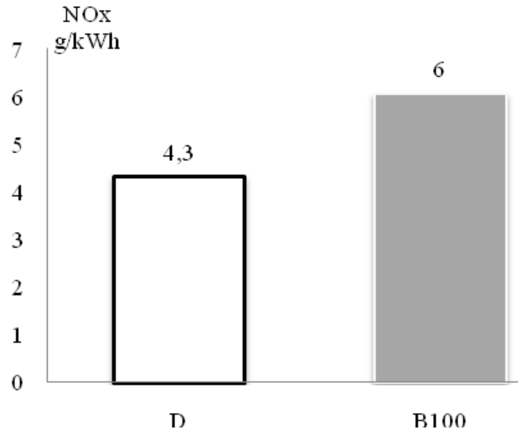

Figure 6. NO_x variation with respect to fuel type

Figure 5 shows CO variation at same operating condition, a significant reduction of CO emission obtained with RME. Higher cetane number of RME causes higher amount of fuel burnt in premixed combusiton phase thus carbon related pollutants decreased considerably. Same trend also shown in figure 6 for CO_2 emissions of RME.

Major contributor of Nitric oxide emission is oxygen in hot burning zone. Higher amount of Nitric oxide can be expected with combustion of oxygenated fuels as like biodiesels. Nitric oxide measurements of RME are shown in figure 6, almost 40% increase obtained with biodiesel. The higher cetane number of biodiesel fuel as compared to diesel fuel can explain the above mentioned difference of biodiesel on NO_x emissions.

4.Conclusion

Biodiesel can be a fuel alternative for CI engines with its' environment friendly production process. Also lower pollutant level of carbon related compounds are possible with using biodiesel. Althougth Nitric oxide emissions tend to increase with biodiesel.

Brake effective power of test engine decreased 13% and BSFC increased 9% with neat RME when compared to diesel fuel. Rapeseed oil methyl ester exposed lower carbon monoxide and carbon dioxide results in this study, which were decreased 50% and 12% respectively but 40% increase of NO_x emission obtained.

Nomenclature

FAME	Fatty acid methyl ester
RME	Rapeseed methyl ester
BSFC	Brake specific fuel consumption
BMEP	Brake mean effective pressure
NO_x	Nitric oxide
CO	Carbon Monoxide
CO2	Carbon Dioxide
B5	Blend with 5%vol. biodiesel with 95%vol. diesel fuel.
B10	Blend with 10%vol. biodiesel with 90%vol. diesel fuel.
B20	Blend with 20%vol. biodiesel with 80%vol. diesel fuel.
B100	Neat biodiesel

[1] U.S. Energy Information Administration, independent statics and analysis. http://www.eia.doe.gov

[2]Ayhan Demirbas,Relationships derived from physical properties of vegetable oil and biodiesel fuels, Fuel 87 (2008) 1743–1748

[3]Gvidonas Labeckas, Stasys Slavinskas, Performance of direct-injection off-road diesel engine on rapeseed oil., Renewable Energy 31 (2006) 849–863

[4]A.S.Ramadhas,S.Jayaraj,C.Muraleedharan, Characterization and effect of using rubber seed oil as fuel in the compression ignition engines, Renewable Energy 30 (2005) 795–803

[5] Norbert Hemmerlein, Volker Korte, and Herwig Richter, Günter Schröder, Performance, Exhaust Emissions and durability of Modern Diesel Engines Running on Rapeseed Oil, Sae Technical Paper Series, 910848

[6]Andre Boehman,Mahabubul Alam, Juhun Song, Ragini Acharya, Jim Szybist, Vince Zello, Fuel formulation Effects on diesel fuel injection, combustion, emissions and emission control. Proceedings of DOE 2003 Diesel Engine Emission Reduction Conference,2003,Newport,RI

[7] Chao He, Yunshan Ge, Jianwei Tan and Xiukun Han, Spray properties of alternative fuels: A comparative analysis of biodiesel and diesel, Int. J. Energy Res. 2008; 32:1329–1338

[8] Su Han Park, Hyung Jun Kim, Hyun Kyu Suh, Chang Sik Lee, A study on the fuel injection and atomization characteristics of soybean oil methyl ester (SME) , International Journal of Heat and Fluid Flow 30 (2009) 108–116

[9] C.D. Rakopoulos, K.A. Antonopoulos, D.C. Rakopoulos, Multi-zone modeling of Diesel engine fuel spray development with vegetable oil, bio-diesel or Diesel fuels, Energy Conversion and Management 47 (2006) 1550–1573

[10] Stanislav Pehan, Marta Svoljšak Jerman, Marko Kegl, Breda Kegl, Biodiesel influence on tribology characteristics of a diesel engine., Fuel 88 (2009) 970–979

[11] Jürgen Krahl, Gerhard Knothe,Axel Munack,Yvonne Ruschel, Olaf Schröder, Ernst Hallier, Götz Westphal, Jürgen Bünger, Comparison of exhaust emissions and their mutagenicity from the combustion of biodiesel, vegetable oil, gas-to-liquid and petrodiesel fuels, Fuel 88 (2009) 1064–1069

[12] Mustafa Canakci, Ahmet Necati Ozsezen, Erol Arcaklioglu, Ahmet Erdil, Prediction of performance and exhaust emissions of a diesel engine fueled with biodiesel produced from waste frying palm oil, Expert Systems with Applications 36 (2009) 9268–9280

[13] Michael S. Graboski, Robert L. McCormick, Combustion of Fat and Vegetable Oil Derived Fuels in Diesel Engines, *Prog. Energy Combust. Sci.* Vol. 24, pp. 125-164, 1998

[14] A. Senatore and M. Cardone, V. Rocco, M. V. Prati, A Comparative Analysis of Combustion Process in D. I. Diesel Engine Fueled with Biodiesel and Diesel Fuel, , Sae Technical Paper Series, 2000-01-0691

[15]Magin Lapuerta,Octavio Armas, Jose Rodriguez-Fernandez, Effect of biodiesel fuels on diesel engine emissions, Progress in Energy and Combustion Science 34 (2008) 198–223

[16]Gvidonas Labeckas, Stasys Slavinskas, The effect of rapeseed oil methyl ester on direct injection Diesel engine performance and exhaust emissions, Energy Conversion and Management 47 (2006) 1954–1967