Turkish J. Eng. Env. Sci.
29 (2005) , 89 – 94.

Experimental Performance Analysis of Biodiesel, Traditional Diesel and Biodiesel with Glycerine

Muammer ÖZKAN, Alp T. ERGENÇ, Orhan DENİZ
Yıldız Technical Universiyt, Department of Mechanical Engineering
İstanbul-TURKEY
e-mail: aergenc@yildiz.edu.tr

Received 23.02.2004

Abstract

Biodiesel, traditional Diesel and biodiesel with glycerine were used as the fuel of a direct injection compression ignition engine. The torque, brake power and fuel consumption values associated with these fuels were determined under certain operating conditions. Effective efficiency, effective pressure and SFC values were calculated according to the formulae given in the Appendix. The obtained results were compared and it was noted that all fuels yielded similar results at some points. However, biodiesel and biodiesel with glycerine gave different values under the same conditions. According to these results, glycerine affects engine performance under certain engine speed conditions.

Key words: Alternative fuel, Diesel engine, Performance, Biodiesel, Glycerine.

Introduction

Alternative fuel studies are driven by the need for new energy sources and the need to protect the environment. One hundred years ago, Rudolf Diesel tested vegetable oils as a fuel for his engine (Shay, 1993). Biodiesel as a vegetable oil, biodegradable and non-toxic, has low emission profiles and so is environmentally beneficial (Krawezyk, 1996).

Biodiesel is a chemically produced vegetable oil to replace the traditional Diesel fuel. The chemical process is known as transesterfication and consists of treating vegetable oils, like soybean, sunflower and rapeseed, with reactants (methanol or ethanol) to obtain a methyl or ethyl ester and glycerine. In transesterfication, one ester is converted to another. The reaction is catalysed by a reaction with either an acid or base and involves a reaction with an alcohol, typically methanol if a biodiesel fuel is the desired product (Graboski and Mc. Cormick, 1998).

Fats and oils are made up of 1 mole of glycerol and 3 moles of fatty acids and are commonly referred to as triglycerides (Sonntag, 1979). The chemical scheme is shown in Figure 1. On the other hand, biodiesel can be made from waste oils. A method has been described for producing esters from waste cooking oils containing significant quantities of free fatty acids liberated during the cooking process (Graboski and Mc. Cormick, 1998).

Biodiesel can be used directly in compression ignition engines with no substantial modifications to the engine (Laforgia and Ardito, 1994). Biodiesel contains no sulphur and therefore this is the important point in terms of future European regulations.

The aim of the study was to investigate the effect of waste cooking oil biodiesel fuels on CI engine performance and to investigate the effect of glycerine in waste cooking oil on engine performance.

A single cylinder, 4 stroke, direct injection diesel engine has been used to measure the general performance of biodiesel and traditional Diesel. Moreover, to investigate the effects of glycerine on engine performance, biodiesel with glycerine was tested.

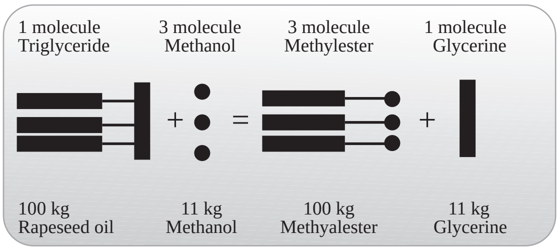

Figure 1. Transesterification process (Laforgia and Ardito, 1994).

Experimental Apparatus

To measure the engine speed a digital tachometer (Lutron DT-2234) was used. To load the engine a 6.5 kW generator-electrolysis unit was used which has an arm for taking the brake force out of the system. A digital balance was used to measure the force from the generator. The gravity measuring method was chosen to measure the engine fuel consumption and another digital balance was used to measure the gravity differences of the fuel in the fuel tank. The effective pressure, effective efficiency and SFC values were calculated according to the formulae given in the Appendix (Adler, 1996). The test bench is shown in Figure 2.

Test procedure

A single cylinder Lombardini LDA 450 Diesel engine, whose characteristics are listed in Table 1, was used for the experimental analysis. Fuel was supplied to the engine from an outside tank. All runs started with a 10-min warm-up period prior to data collection.

The data measured during the tests included engine speed, brake torque, and fuel consumption. The fuel consumption was determined by measuring the time for the consumption of a fixed mass (10 g).

During all tests, the injection timing (25^oBTDC) was not altered and the rack position was maintained at full. The engine speed was varied by adjusting the load knob on the control panel of the test rig while maintaining the full rack position.

The tests were performed with traditional Diesel fuel, biodiesel without glycerine and biodiesel with glycerine. The experiment results of the traditional Diesel fuel are listed in Table 2 and those of the biodiesel fuels are listed in Tables 3 and 4. Using these tables, the performance curves for all fuels are shown together for comparison purposes.

Figure 3 shows the brake power values for the 3 fuels at different engine speeds. The maximum brake power values of biodiesel, Diesel and biodiesel with glycerine were obtained at 2750, 2500 and 2000 rpm, respectively. According to these values, the traditional Diesel fuel has the greatest brake power.

Table 1. Technical specifications of LDA 450.

Total displacement	454 cm^3
Number of cylinders	1
Injection timing	25° BTDC
Stroke	80 mm
Bore	85 mm
Compression ratio	17.5/1
Max. torque at 1700 rpm	28.5 Nm
Max. power	5.5 kW

Table 2. The results of experiments with the traditional Diesel fuel.

	Eng. Speed	**Torque**	**Power**	**S.F. C.**	**Eff.Efficiency**	**Eff.Pressure**
	Rpm	(Nm)	(kW)	(g/kWh)	(%)	(bar)
1	1000	20.2	2.119	380.498	22.6	5.600
2	1250	20.8	2.716	395.718	22.7	5.744
3	1500	21.0	3.300	346.706	24.8	5.816
4	1750	19.9	3.641	324.722	26.5	5.500
5	2000	19.9	4.156	304.825	28.2	5.493
6	2250	19.8	4.651	282.468	30.4	5.464
7	2500	19.9	5.208	272.411	31.6	5.507
8	2750	16.9	4.877	290.880	29.6	4.688
9	3000	13.5	4.229	349.462	24.6	3.726

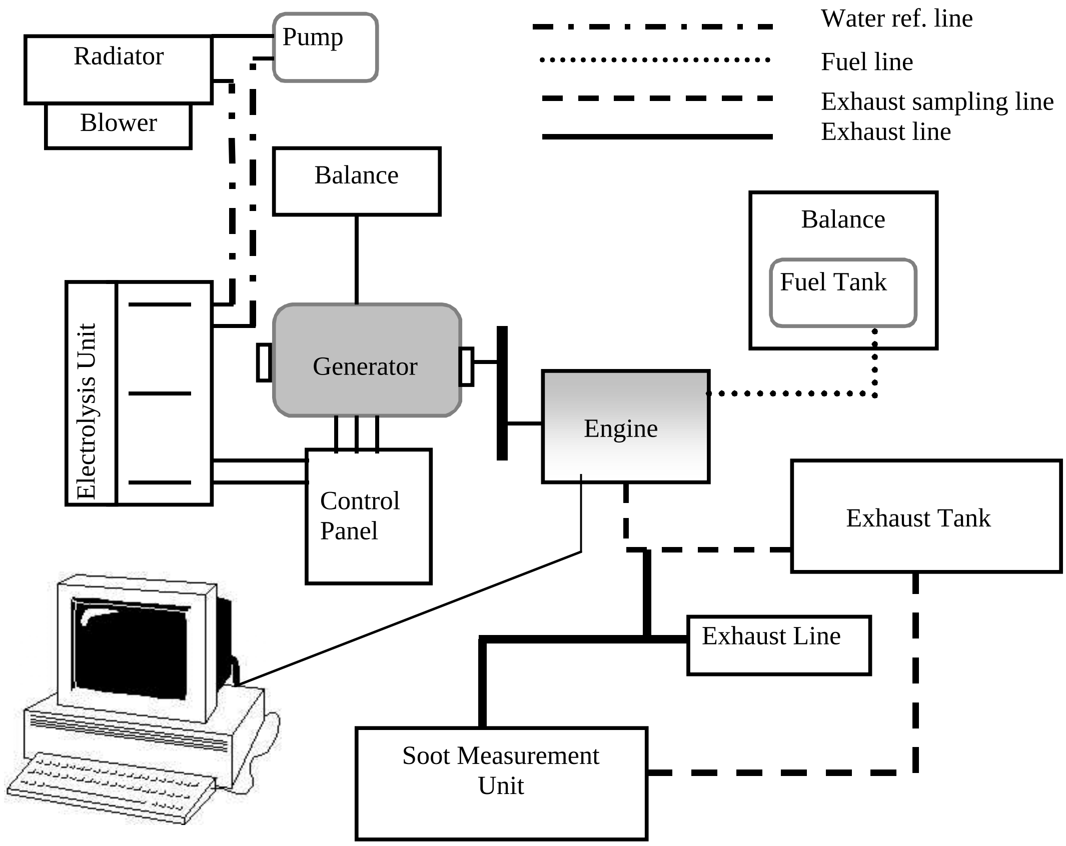

Figure 2. Test bench.

Table 3. The results of experiments with the traditional biodiesel fuel without glycerine.

	Eng. Speed	**Torque**	**Power**	**S.F. C.**	**Eff.Efficiency**	**Eff.Pressure**
	Rpm	(Nm)	(kW)	(g/kWh)	(%)	(bar)
1	1000	17.8	1.861	471.859	18.226	4.919
2	1250	17.2	2.246	433.236	19.851	4.749
3	1500	17.2	2.695	417.441	20.602	4.749
4	1750	17.7	3.234	359.089	23.950	4.885
5	2000	18.0	3.768	341.232	25.203	4.980
6	2250	18.4	4.331	307.841	27.936	5.089
7	2500	15.9	4.171	331.977	25.905	4.410
8	2750	15.3	4.390	341.664	25.171	4.220
9	3000	9.6	3.018	372.715	23.074	2.660

Figure 4. shows the variation of torque with engine speed. The maximum torque values are about 21.0 Nm at 1500 rpm for the Diesel fuel, 19.7 Nm at 1500 rpm for the biodiesel with glycerine, and 18.4 Nm at 2250 rpm for the biodiesel. The torque values of traditional Diesel are greater than those of biodiesel. The torque values of biodiesel with glycerine are greater than those of biodiesel without glycerine up to 2000 rpm. These results indicate that glycerine has an effect on engine torque.

Table 4. The results of experiments with the traditional biodiesel fuel with glycerine.

	Eng. Speed	Torque	Power	S.F. C.	Eff.Efficiency	Eff.Pressure
	(rpm)	(Nm)	(kW)	(g/kWh)	(%)	(bar)
1	1250	19.4	2.539	367.540	23.4	5.370
2	1500	19.7	3.096	369.516	23.3	5.457
3	1750	19.0	3.494	376.020	22.9	5.277
4	2000	19.2	4.025	314.698	27.3	5.320
5	2250	14.7	3.453	366.869	23.4	4.057
6	2500	13.1	3.436	344.103	24.5	3.633
7	2750	12.2	3.510	336.781	25.5	3.374
8	3000	6.5	2.037	600.400	14.3	1.795

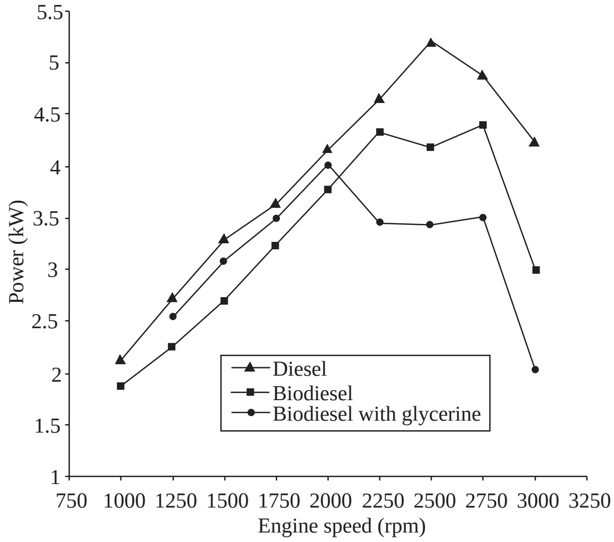

Figure 3. Variation of brake power values.

The variations of specific fuel consumption (SFC) of these fuels are presented in Figure 5. The SFC values of biodiesel decrease until 2250 rpm but those of traditional Diesel decrease up to 2500 rpm. In contrast to Nwafor's study (2003), there is a significant difference noted between traditional Diesel and biodiesel with glycerine at 3000 rpm. Nevertheless, the SFC values of traditional Diesel and biodiesel without glycerine show similar behaviour, as in Nwafor's study.

The SFC values of the 3 fuels were calculated with the formulae given in the Appendix. The minimum SFC value with traditional Diesel was 272.4 g/kWh at 2500 rpm and with biodiesel and biodiesel with glycerine it was 307.8 g/kWh and 314.6 g/kWh at 2250 and 2000 rpm, respectively.

The effective efficiency values of the 3 fuels were calculated with the formulae given in the Appendix. The results of effective efficiency are presented in Figure 6.

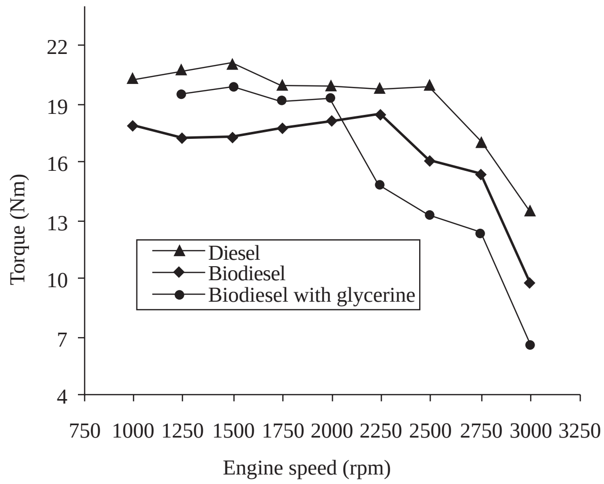

Figure 4. Variation of torque values.

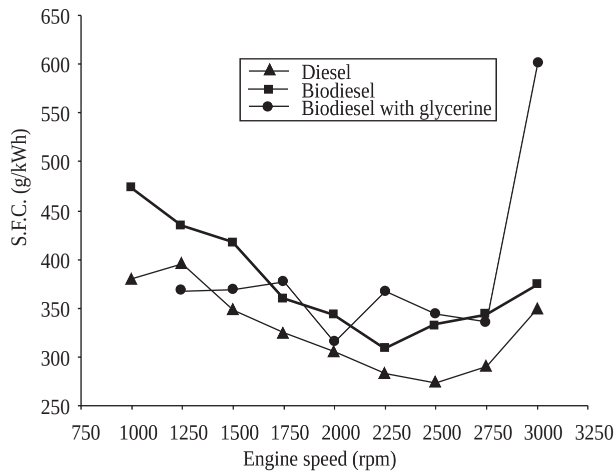

Figure 5. Variation of specific fuel consumption values.

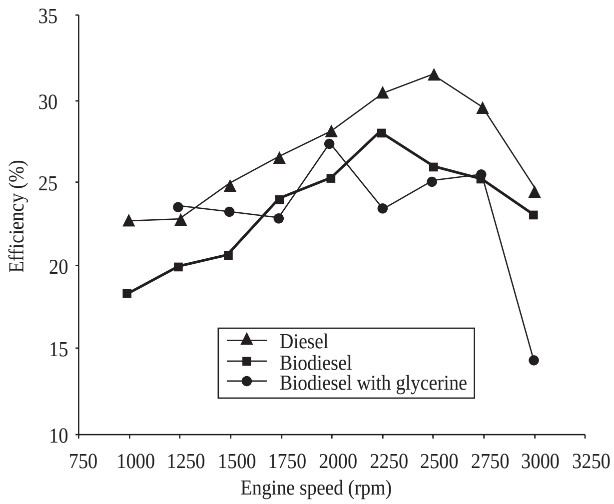

Figure 6. Variation of effective efficiency values.

The traditional Diesel has the highest effective efficiency value as a result of low SFC. In this figure there is a significant increase in the efficiency value of biodiesel with glycerine at 3000 rpm because of the high SFC.

Figure 7 shows the effective pressure values of the 3 fuels calculated according to the formulae in the Appendix. The Diesel and biodiesel with glycerine show similar effective pressure values up to 2000 rpm. After that point the effective pressure value of biodiesel with glycerine decreases more than, that of the other 2 fuels.

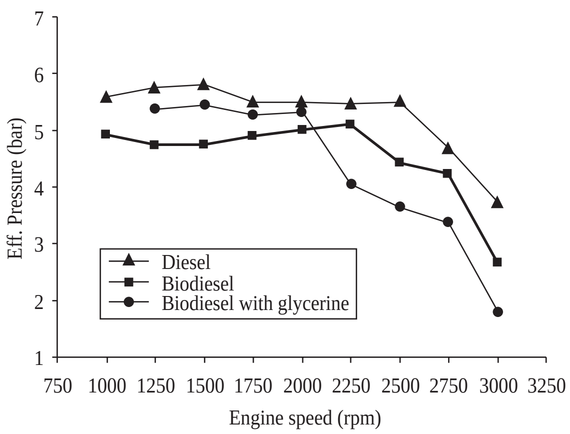

Figure 7. Variation of effective pressure.

Results and Discussion

The variations of brake power values of biodiesel, Diesel and biodiesel with glycerine show similar behaviours until 2000 rpm. Above this value, the traditional Diesel gives high brake power values. The observed maximum brake power with traditional Diesel is 25% higher than that with biodiesel and 52% higher than that with biodiesel with glycerine at 2500 rpm.

The maximum torque values were observed as about 21.0 Nm, 19.7 Nm, and 18.4 Nm at 1500 rpm for Diesel, and biodiesel fuel with glycerine and at 2250 rpm for biodiesel fuel, respectively.

The specific fuel consumptions of the 3 fuels took different values. The minimum SFC value with traditional Diesel was 272.4 g/kWh at 2500 rpm. However, SFC values for biodiesel and biodiesel with glycerine were 307.8 g/kWh, and 314.6 g/kWh at 2250, and 2000 rpm, respectively.

The SFC value of Diesel was 11.5% lower than that of biodiesel with glycerine and 13.4% lower than that of biodiesel.

The traditional Diesel gives the maximum efficiency value at 2500 rpm as a result of low SFC. However, the biodiesel with glycerine gives the minimum efficiency at 3000 rpm.

The effective pressure of biodiesel, biodiesel with glycerine and traditional Diesel took similar values up to 2000 rpm.

According to these results, glycerine has significant effects on engine performance.

Conclusions

In this study, waste cooking oil biodiesel fuels were tested in a single-cylinder DI Diesel engine. It was found that with biodiesel the engine operated smoothly with no notable problems. Compared Diesel fuel, a 25% power loss occured with biodiesel. The perfomance characteristics of biodiesel were closer to those of Diesel fuel. The selling price of waste cooking oil biodiesel fuel is lower than that of Diesel fuel as a result of the recycling of raw materials. Based on these results, it may be concluded that the biodiesel fuels can be used as fuel in Diesel engines with some modifications. Fuel systems should be optimised for biodiesel fuels, because of the high density and gumming properties.

The problems include (1) coking and trumpet formation on the injectors to such an extent that fuel atomization does not occur properly or is even prevented as a result of plugged orifices, (2) carbon deposits, (3) oil ring sticking and (4) thickening and gelling of the lubricating oil as a result of contamination by the vegetable oils (Ma and Hanna, 1999).

References

Ma, F.r., and Hanna, M.A., “Biodiesel Production: A Review”, Bioresource Technology, 70, 1-15, 1999.

Graboski, M.S. and McCormick, R.L., “Combustion of Fat and Vegetable Oil Derived Fuels in Diesel Engines”, Prog. Energy Combust. Sci., 24, 125-164, 1998.

Krawezyk, T., “Biodiesel Alternative Fuels Makes Inroads But Hurdles Remain”. Inform, 7, 801-829, 1996.

Laforgia, D. and Ardito, V., “Biodiesel Fueled Idi Engines, Performances, Emissions and Heat Release Investigation.” Bioresource Technology, 51, 53-59, 1995.

Nwafor, O.M.I., “The Effect of Elevated Fuel Inlet Temperature on Performance of Diesel Engine Running on Neat Vegetable Oil at Constant Speed Conditions” Renewable Energy, 28, 175-179, 2003.

Shay, E.G., “Diesel Fuel from Vegetable Oils: Status and Opportunities” Biomass and Bioenergy 4, 227-242, 1993.

Sonntag, N.O.V., “Structure and Composition of Fats and Oils”, Bailey’s Industrial Oil and Fat Products”, 1, John Wiley and Sons, New York, 1979.

Adler, U., “Automotive Handbook”, Robert Bosch GmbH, Stuttgart, 406-407, 1996.

Appendix

$$P = \frac{M_d.n}{9549}$$

P *Engine power (kW)*
M_d *Engine torque (Nm)*
n *Engine speed (min^{-1})*

$$p = 0.0628\frac{M}{V_H}$$

p *Mean pressure (bar)*
M *Engine torque (Nm)*
V_H *Total displacement (dm^3)*

$$b_e = \frac{m_b.3600}{t_B.P}$$

b_e *Specific fuel consumption (g/kWh)*
m_b *Mass(g)*
t_b *Time (min)*
P *Engine power (kW)*

$$\eta_e = \frac{860}{be.Hu}$$

η_e *Effective efficiency*
b_e *Specific fuel consumption (g/kWh)*
H_u *Specific caloric value (kcal/kg)*