Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2018, 5(10):72-79**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Determining the Effects of the Use of Pure Biodiesel on Engine Components and Wear

Erdal KILIC[1], Yilmaz BAYHAN[2]*, Selcuk ARIN[2]

[1]University of Namik Kemal, Vocational College of Technical Science, Department of Automotive, 59030 Tekirdağ-Turkey
[2]University of Namik Kemal, Faculty of Agriculture, Department of Farm Machinery, 59030 Tekirdağ-Türkiye

Abstract As is known, diesel engine vehicles the use of which is continuously increasing have used petroleum-origin fuels and accordingly the need for fuel has increased in relation to this increase. Decreasing petroleum reserves, and rapid increase in petroleum costs, coupled with increasing air pollution have directed people to seek alternative means of fuels. Biodiesel (refined) of canola and a new FIAT 60-56 model of tractor engine were principal materials of this research. Experiments were carried out for a total of 100 hours while the engine's speed was fixed as 1500 min^{-1}.

The effects of biodiesel were inspected on engine components such as crankshaft trunnion, cylinders and pistons. As a result, there was no significant oval, conical and wear crankshaft, cylinders and pistons. Dark zones, caused biodiesel were observed on crankshaft trunnions and also C residues and stripes were observed around the cylinders. Pure biodiesel (B100) cannot be used in today's engines available in market. It might be an alternative fuel to diesel if some improvements could be achieved on fuel system.

Keywords Biodiesel, engine, crankshaft, cylinder, piston, wear, soot

1. Introduction

The term biodiesel is used to define the simple alkyl esters of fatty acids from vegetable oils, animal fats, and recycled greases when used as fuels for diesel engines, either neat or blended with petroleum diesel. Biodiesel typically is produced from the neat oil or fat by transesterification with an alcohol, usually methanol, in the presence of an alkaline catalyst. Alkali metal hydroxides (typically sodium hydroxide) are the most common catalysts used but other metal catalysts as well as biocatalysts have also been used to catalyze the transesterification reaction. When greases that have high free fatty acid content are used as feedstock, a two-step acid-alkali process is used to convert them to biodiesel. Regardless of the method or feedstock used, the biodiesel must meet established fuel standards both in Europe (Germany DIN 51606) and the United States (ASTM D6751-02) [1].

Internal combustion engines in either major type of operating mode, spark ignition or compression ignition, are expected to continue to dominate the market as the major power source for automotive propulsion for the short to medium term future. This means that gasoline or diesel fuels from conventional fossil hydrocarbon sources or their substitutes will continue to be in demand. This presents two major problems: that of fuel shortages or price rises, through diminishing availability, and that of increasing environmental pollution, including global warming through the greenhouse gas CO2. Both of these problems can be addressed by increased provision of renewable bio-fuel substitutes. This is particularly attractive where there is little indigenous resource of hydrocarbon fuel and where conditions prevail to readily produce the alternatives [2].

Biodiesel is produced in a pure form (100% biodiesel fuel referred to as "B100" or "neat biodiesel"). Neat biodiesel can cause a variety of engine performance problemes such as filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking, and severe engine lubricant degradation. At low ambient temperatures, biodiesel is thicker than conventional diesel fuel, which would limit its use in certain geographic areas. In addition, elastomer compatibility with biodiesel remains unclear; therefore, when biodiesel fuels are used, the condition of seals, hoses, gaskets, and wire coatings should be monitored regularly. There is limited information on the effect of neat biodiesel on engine durability during various environmental conditions. More information is needed to assess the viability of using these fuels over the mileage and operating periods typical of heavy-duty engines. The use of neat biodiesel in place of petroleum-based diesel fuel may reduce visible smoke and particulate emissions, which are of special concern in order diesel engines in non-attainment areas. In addition, B100 can achieve some reduction in reactive hydrocarbons ("HC") and carbon monoxide ("CO") emissions when used in an unmodified diesel engine. Those reductions are attributed to the presence of oxygen in the fuel. Oxygen and other biodiesel characteristics, however, also increase oxides of nitrogen ("NOx") in an unmodified engine. As a result, B100 produces higher NOx emissions than petroleum-based diesel fuel. According to Engine Manufacturers Association, biodisel blends up to a maximum of B5 should not cause engine or fuel system problems, provided the B100 used in the blend meets the requirements of ASTM D 6751, DIN 51606, or EN 14214. Engine manufacturers should be consulted if higher percentage blends are desired [3].

Biofuels derived from bio-resources (biomasses) can be ideal option to replace fossil fuels due to the fact that biofuels have cheap cost of materials to make them; they are renewable; and they are good for the environment given their net zero CO_2 emission [4,5,6]. A variety of fuels can be produced from plant biomass and fatty acids such as ethanol, methanol, butanol and biodiesel [7,8,6]. Compared to conventional fossil fuels, biofuels have several advantages like the source of biofuel is renewable [4,9,10,6], combustion of biofuels produce less toxic compound [9,10] and biofuels can reduce net carbon emissions up to a very low level [4,9,11,6]. Apart from these, biofuels have almost similar combustion properties like conventional fossil fuels. Diesel and gasoline can easily be replaced by biofuels with a little modification to the engines. Alcohol fuels like ethanol, methanol and butanol can replace gasoline and suitable to use in spark-ignition engines [6].

The aim of this paper was to determine the possibility of using pure biodiesel (B100) and observe the effects on engine oil and parts for diesel engines. In addition to these, it also aimed at giving an idea for further researchers which will be done on about biodiesel.

2. Experimental Setup and Procedures

Relevant properties of the test fuels used in the research are listed in Table 1 and the specifications of the test engine (direct injection diesel engine) are shown in Table 2.

Table 1: Properties of the test fuels

Fuels	Result	Specification DIN EN 14214	
		Min	Max
Density at 15^o C (kg/m^3)	888	860	900
Specific combustion enthalpy (MJ/kg)	39,80		
Cetane number	51,3	51	-----
Iodine number	129,7	----	130
Kinetic viscosity (40^o C mm^2/s)	4,4	3,5	5,0
Sulfur content (mg/kg)	≤ 1 ppm	----	10
Percentage of humidity (%)	0,13		
Acid value (mg KOH/g)	0,336	----	0,5
Diglyceride content % (m/m)	≤0,2	----	0,2
Triglyceride content % (m/m)	≤0,2		0,2
Monoglyceride content % (m/m)	≤0,8	----	0,8
Total Glycerol % (m/m)	≤0,25	----	0,25

Table 2: Properties of the diesel engine

Engine	**FIAT**
Model	60-56
Type	Water-cooled, four stroke
Combustion	Direct injection (DI) and naturally aspirated
Number of cylinders	3
Bore and stroke	104 X 115 mm
Displacement	2931 cm^3
Compression ratio	17:1
Nominal rated power	44 kW
Maximum torque speed	1500 rpm
Combustion chamber	Swirl chamber

In this study, an experimental engine was operated at 1500 rpm as constant throughout the wear period for pure biodiesel. The engine was operated for 100 h for each test of biodiesel. For three tested biodiesels, the engine was operated for a total of 300 hours [12].

Components were investigated at the end of every 100 hours operation period by disassembling the engine. It is observed that there was worn on crankshaft, piston, and cylinder. Conical and oval wear on piston were determined. Measurements were done at the points marked in Figure-1.

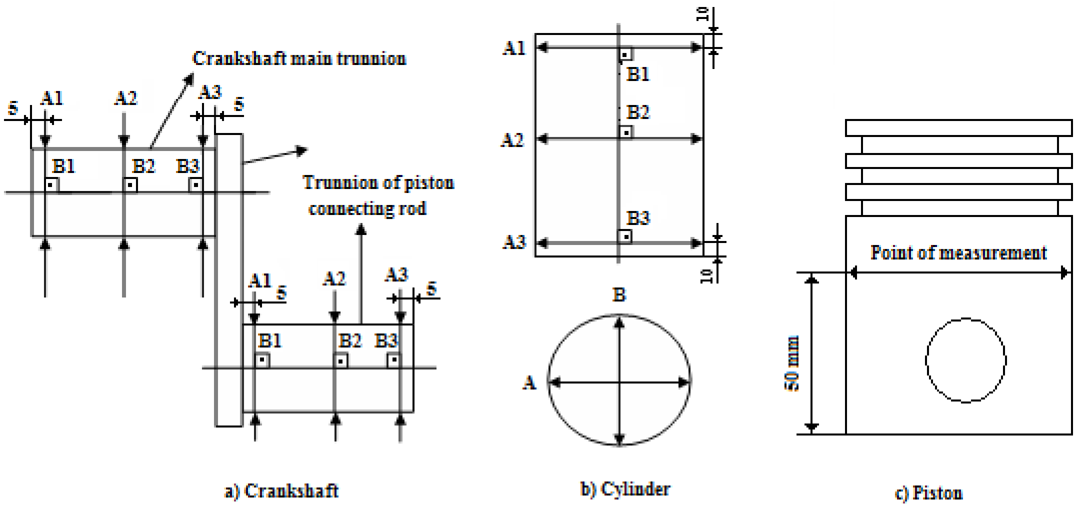

Figure 1: Measurement of points on components of motor

Then oval and conical shape and wear are calculated by the equations. On the other hand, the amount of residues stained (soot) was weighted using an electronic balance (Mark of PRECISA and model of XB220A, with an accuracy of 0.0001 g).

$$OCCP_{Max} = D_{AnMax} - D_{BnMax}$$

$$OCCP_{Min} = D_{AnMin} - D_{BnMin}$$

$$CA_{axis}\,CCP = D_{AnMax} - D_{AnMin}$$

$$CB_{axis}\,CCP = D_{BnMax} - D_{BnMin}$$

$$WC = D_{Initial} - D_{AnMax} \text{ or } D_{BnMax}$$

$$WCP = D_{Initial} - D_{AnMin} \text{ or } D_{BnMin}$$

Where:

$OCCP_{Max}$	: Max. Oval for cylinder crankshaft and piston
D_{AnMax}	: Maximum diameter of A axis
D_{BnMax}	: Maximum diameter of B axis
$OCCP_{Min}$	: Min. Oval for cylinder crankshaft and piston
D_{AnMin}	: Minimum diameter of A axis

D_{BnMin} : Minimum diameter of B axis
$CA_{axis}CCP$: Max. Conical for A axis in cylinder crankshaft and piston
$CB_{axis}CCP$: Max. Conical for B axis in cylinder crankshaft and piston
WC : Wear for cylinder
WCP : Wear for crankshaft and piston
$D_{Initial}$: Original diameter

3. Result and Discussion

3.1. Crankshaft

There was no significant oval and conical wear on crankshaft. The results are shown in Table 3. Dark zone caused by biodiesel were observed on crankshaft trunnions (Figure-2), but shoot was not found on crankshaft.

Table 3: Point of measurement in crankshaft for oval, conical and wear

Crankshaft main trunnion	Replication	Point of measurement						Oval	Conical	Wear
		A1	B1	A2	B2	A3	B3			
1	1	79.81	79.81	79.81	79.81	79.81	79.81	0	0	0
	2	79.81	79.81	79.81	79.81	79.81	79.81			
	3	79.81	79.81	79.81	79.81	79.81	79.81			
2	1	79.81	79.81	79.81	79.81	79.81	79.81	0	0	0
	2	79.81	79.81	79.81	79.81	79.81	79.81			
	3	79.81	79.81	79.81	79.81	79.81	79.81			
3	1	79.81	79.81	79.81	79.81	79.81	79.81	0	0	0
	2	79.81	79.81	79.81	79.81	79.81	79.81			
	3	79.81	79.81	79.81	79.81	79.81	79.81			
4	1	79.81	79.81	79.81	79.81	79.81	79.81	0	0	0
	2	79.81	79.81	79.81	79.81	79.81	79.81			
	3	79.81	79.81	79.81	79.81	79.81	79.81			

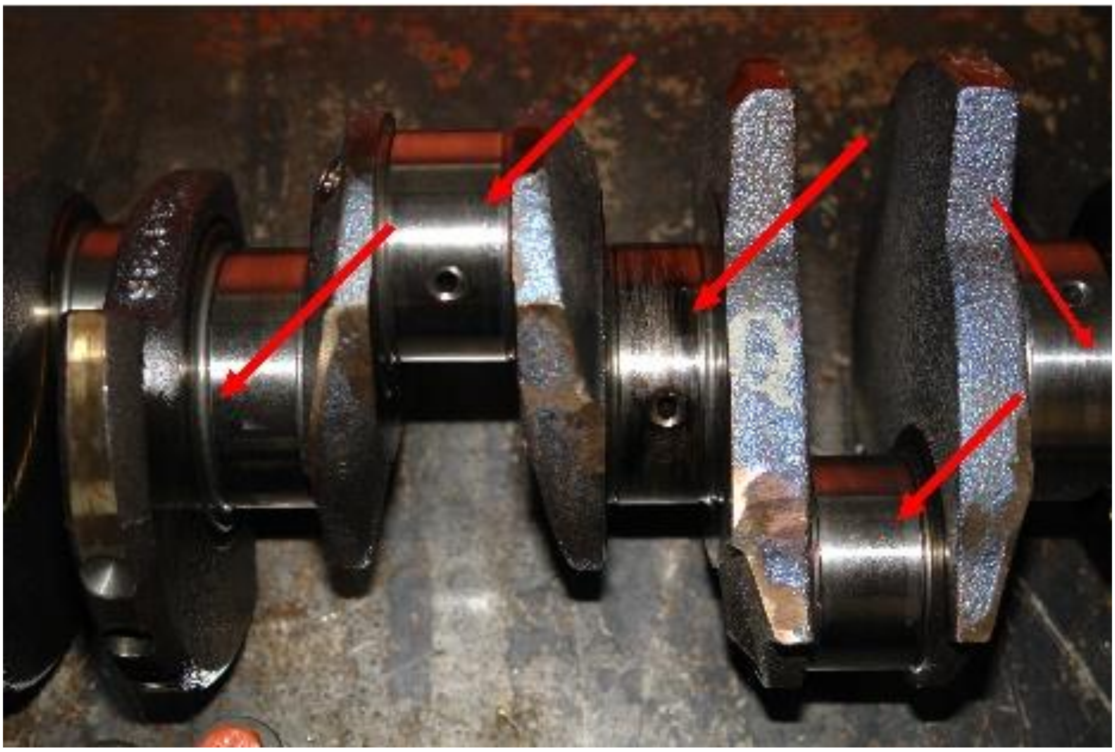

Figure 2: Dark zone caused biodiesel on crankshaft trunnions

3.2. Cylinder

Oval and conical wear were not observed in cylinders but vertical stripes were found on TDC around the cylinders (Figure 3). The results were shown in Table 4. Thick C residues were obtained in cylinders (Figure 4).

Figure 3: Vertical stripes on cylinders

Figure 4: Thick C residues in cylinders

Table 4: Data on cylinder for oval, conical and wear

Cyclinder	Replication	Point of measurement						Oval	Conical	Wear
		A1	B1	A2	B2	A3	B3			
1	1	104.00	104.00	104.00	104.00	104.00	104.00	0	0	0
	2	104.00	104.00	104.00	104.00	104.00	104.00			
	3	104.00	104.00	104.00	104.00	104.00	104.00			
2	1	104.00	104.00	104.00	104.00	104.00	104.00	0	0	0
	2	104.00	104.00	104.00	104.00	104.00	104.00			
	3	104.00	104.00	104.00	104.00	104.00	104.00			
3	1	104.00	104.00	104.00	104.00	104.00	104.00	0	0	0
	2	104.00	104.00	104.00	104.00	104.00	104.00			
	3	104.00	104.00	104.00	104.00	104.00	104.00			

3.3. Piston

There was no significant oval, conical and wear on pistons. The results are shown in Table-5. Intensive C residues and stripes were observed around the compression and oil rings zones of cylinders. C residue may cause a lack of compression and oil rings failure.

Researches recommend a mixture rate of biodiesel fuel which is B5, B10 or B20 level. Besides, B100 might cause some failures in the injection system [3,13]. However, B100 could be used if fuel injection system were redesigned as properly. Bona et al. [14] pointed out that among biofuels, methylester is the most important within the EU, although its use in a pure form may give rise to several negative effects on diesel engine functioning.

Table 5: Values of oval, conical and wear in trunnion of piston connecting rod

Piston	Catalog value	Repli-cation	Trunnion of piston connecting rod	Wear
1	103.812-103.826	1	103.81	0
		2	103.81	
		3	103.81	
2	103.812-103.826	1	103.82	0
		2	103.82	
		3	103.82	
3	103.812-103.826	1	103.82	0
		2	103.82	
		3	103.82	

3.4. Soot

Amount of residue accumulated on engine components after each 100 hours running periods are shown in Table-6. Those kinds of unburned fuel residues indicate that fuel system is not suitable for biodiesel.

Table 6: Total amount of soot on the engine parts

Cylinder	Replication	Total soot on valves	Total soot in combustion chamber and surroundings
1	1	31,874	26,887
	2	21,874	25,377
	3	21,779	25,348
	Average	**25,176**	**25,871**
2	1	28,409	24,372
	2	25,919	21,392
	3	26,125	21,267
	Average	**26,818**	**22,344**
3	1	29,600	25,087
	2	26,800	22,446
	3	26,745	22,433
	Average	**27,715**	**23,322**

The residue on the engine parts were analyzed by using ICP-OES. On the basis of this analysis, the contents Na, Ca, P, Fe, Al, Zn, S, Cr, Si, Pb, Mg, Mn, Cu, Sn, Ni, B, As, Ag, Co, Cd, Pt, Ti were determined (Figure 5 and Figure 6). These elements which are components of motor oils and motor alloys lead to a build-up of residue on motor parts as a result of wear and burning petroluem. Such residue causes qucik wear and compression leakeage in motors. If such elements are released into the atmosphere together with exhaust gases, they cause environmental pollution. Murillo et al. [15] investigated the performance and emissions of neat diesel, pure biodiesel, and biodiesel–diesel blend in marine outboard diesel engines without major modification to the engines. They found that blend containing up to about 25% biodiesel gave a lower NOx emission than pure diesel. When the biodiesel percentage increased above 25%, the NOx emission increased, and for B100, it was found to be 16% higher than that of conventional diesel [6].

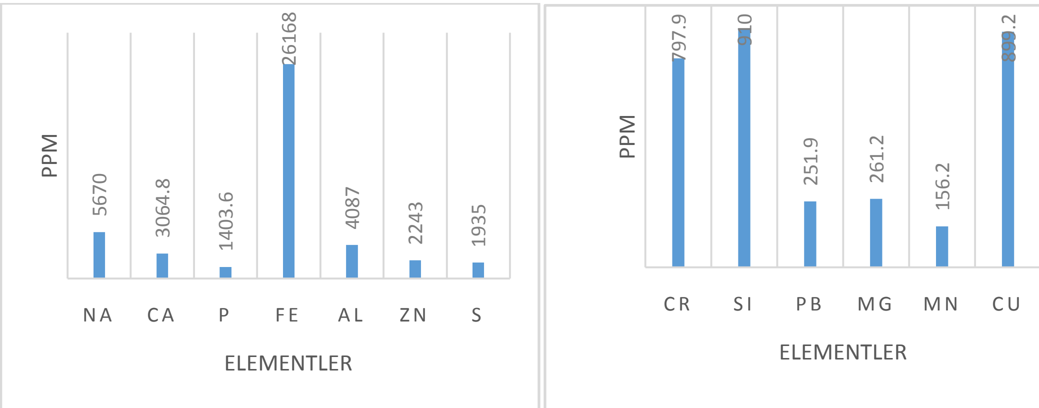

Figure 5: The results of the analysis of soot on the engine parts from ICP-OES

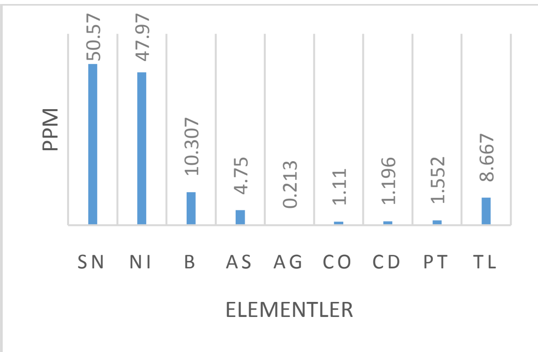

Figure 6: The results of the analysis of soot on the engine parts from ICP-OES

4. Conclusion

Pure biodiesel (B100) can't use the today's engine in market. It might be an alternative fuel to diesel if some improvements could be achieved on parts of engine. For some darkened and clogged zones are observed on crankshaft, cylinder and piston. On the other hand, the parts of engine made of plastic material are destroyed. As a result, neat biodiesel caused a variety of engine performance problems, such as filter plugging, injector coking, piston ring sticking and breaking, elastomer seal swelling and hardening/cracking and severe engine lubricant degradation. But, noise level of engine running biodiesel was lower than that which runs on diesel. Exhaust emission spread in environment was also low.

It is recommended for using biodiesel:

- Pistons chamber combination, shape of valves, compression and oil rings need a new design criteria regarding to biodiesel features,
- Appropriate construction of engine components for biodiesel,
- A new construction of fuel system suits to biodiesel characteristics,
- It is recommended that in order to stop environmental pollution resulting from metal particle release during wear together with other particles particle filters should be used on exhaust systems.

Reference

[1]. Foglia, T.A., Jones, K.C. & Phillips, J.G. (2005). Determination of biodiesel and triacylglycerols in diesel fuel by LC. Chromatographia, 62, August (No. ¾): 115-119.

[2]. Crookes, R.J. (2006). Comparative bio-fuel performance in internal combustion engines. *Biomass and Bioenergy*, 30: 461-468.

[3]. Anonymous, (2003). *Tecnical statement on the use of biodiesel fuel in compression ignition engines*. http://www.globalbioenergy.org/uploads/media/0302_EMA_-_Technical_statement_on_the_use_of_biodiesel_fuel_in_compression_ignition_engines.pdf. Engine Manufacturers Association, Two North LaSalle Street Suite 2200 Chicago, Illinois, 60602, February 2003.

[4]. Razzak, S.A., Hossain, M.M., Lucky, R.A., Bassi, A.S. & Lasa, H., (2013). Integrated CO2 capture, wastewater treatment and biofuel production by microalgae culturing—a review. *Renewable and Sustainable Energy Reviews*, 27:622–653.

[5]. Elsolh, N.E.M. (2011). The manufacture of biodiesel from the used vegetable oil. A thesis submitted to the Faculty of Engineering at Kassel and Cairo Universities for the degree of Master of Science, Kassel, 28 Feb. 2011.

[6]. Oumer, A.N., Hasan, M.M., Baheta, A.T., Mamat, R., Abdullah, A.A., (2018). Bio-based liquid fuels as a source of renewable energy: A review. *Renewable and Sustainable Energy Reviews*, 88: 82–98.

[7]. Demirbas, A. (2008). Comparison of transesterification methods for production of biodiesel from vegetable oils and fats. *Energy Convers Manag*; 49:125–30.

[8]. Foukis, A., Gkini, O.A., Stergiou, P.Y., Sakkas, V.A., Dima, A., Boura, K., et al., 2017. Sustainable production of a new generation biofuel by lipase-catalyzed esterification of fatty acids from liquid industrial waste biomass. *Bioresour Technol*, 238: 122–128.

[9]. Surriya, O., Saleem, S.S., Waqar, K., Kazi, A.G. & Öztürk, M., (2015). Bio-fuels: a blessing in disguise. *Phytoremediat Green Energy: Springer*, 11–54.

[10]. Nigam, P.S. & Singh A., (2011). Production of liquid biofuels from renewable resources. Progress Energy Combust Sci; 37:52–68.

[11]. Dragone G, Fernandes BD, Vicente AA. & Teixeira JA., 2010. Third generation biofuels from microalgae. *Curr Res Technol Educ Top Appl Microbiol Microb Biotechnol*, 2: 1355–66.

[12]. Kalam M.A. & Masjuki, H.H. (2002). Biodiesel from palm oil-an analysis of its properties and potential. *Biomass and Bioenergy*, 23, 471-479.

[13]. Anonymous, (2004). *Biomass, Biodiesel handling and use guidelines.* U.S. Department of Energy, Energy Efficiency and Renewable Energy, DOE/GO-102004-1999, October, 2004.

[14]. Bona, S., Mosca, G. & Vamerali, T. (1999). Oil crops for biodiesel production in Italy. *Renewable Energy*, 16, 1053-1056.

[15]. Murillo, S., Míguez, J.L., Porteiro, J., Granada, E. & Morán, J.C., 2007. Performance and exhaust emissions in the use of biodiesel in outboard diesel engines. *Fuel*; 86:1765–1771.