Power and Torque Characteristics of Diesel Engine Fuelled by Palm-Kernel Oil Biodiesel

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Abstract

Short-term engine performance tests were carried out on test diesel engine fuelled with Palm kernel oil (PKO) biodiesel. The biodiesel fuel was produced through transesterification process using 100g PKO, 20.0% ethanol (wt%), 1.0% potassium hydroxide catalyst at 60°C reaction temperature and 90min. reaction time. The diesel engine was attached to a general electric dynamometer. Torque and power delivered by the engine were monitored throughout the 24-hour test duration at 1300, 1500, 1700, 2000, 2250 and 2500rpm. At all engine speeds tested, results showed that torque and power outputs for PKO biodiesel were generally lower than those for petroleum diesel. Also, Peak torque for PKO biodiesel occurred at a lower engine speed compared to diesel.

Keywords

Palm kernel oil; Biodiesel; Power; Torque; Diesel engine.

Introduction

Instability in world petroleum market occasioned by perpetual rise in petroleum prices, increasing threat to environment from exhaust emissions, global warming and rapidly dwindling crude oil deposits amongst other factors have been reported to be responsible for the recent attention focused on the search for cheaper, environmentally friendly and renewable source of fuel [1-3]. One such source is biomass. Studies have been conducted on biomass-based fuel such as alcohol, biogas and vegetable oil as possible substitute for petroleum based fuels [3, 4].

Reports have shown that vegetable oils are possible alternative fuel for diesel engine. However, problems such as injector coking, thickening of lubricants and oil deposits were recorded on extended operation of diesel engine fuelled with neat or straight vegetable oil (SVO) [3,4]. The observed problems have been attributed to the high viscosity of SVO. Reductions in viscosities of neat vegetable oils such as soy oil, rapeseed, canola, safflower linseed oil and coconut oil have been recorded through transesterification process [5, 6]. Other oil crop investigated includes Palm oil, Jatropha curcus, Tigernut, Rice bran, Palm kernel oil and cottonseed oil [3, 8-10].

Transesterification is the process of using an alcohol (e.g., methanol or ethanol) in the presence of a catalyst, such as sodium hydroxide or potassium hydroxide, to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oil (Biodiesel) with glycerol as a by-product. Biodiesel has also been obtained from animal fats and waste restaurant oils. A few published works on laboratory production and testing of PKO biodiesel as alternative fuel have produced promising results through series of ASTM standard fuel tests [6, 11].

Satisfactory results have been recorded from short-term as well as long-term tests carried out on diesel engines using biodiesel from different feedstock as well as their blends with conventional diesel as fuel [2, 12-16]. Korus *et al.* (1995) [13] conducted rapid engine test to measure injector fouling in diesel engines using vegetable oil fuels. Peterson and Reece (1994) [12] conducted tests on ethyl and methyl esters of rapeseed oil, while Peterson *et al.* (1995a;b) [14,15] worked on the production and testing of ethyl and methyl esters of canola, rapeseed, soybean oils and beef tallow as well as hydrogenated soy ethyl ester. Not much could be found in the literature on engine performance characteristics of PKO-biodiesel. This work therefore conducts some short-term engine performance tests on diesel engine fuelled with local PKO biodiesel with a view to monitoring torque and power output of the engine.

Material and Method

Short-term Engine Performance Tests using PKO-Biodiesel

A 24-hour engine performance testing of the PKO biodiesel fuel was carried out on a test diesel engine. The engine used was a four stroke, four cylinders, turbocharged, direct injected John Deere 4045TF diesel engine with specifications indicated in Table 1. The four cylinder diesel engine was attached to a general electric dynamometer. The dynamometer was of 112kW general electric model TLC2544 direct current (d.c) specification. Torque and power delivered by the engine were monitored throughout the testing.

Table 1. Diesel engine specification

Engine Parameters	Values / Specifications
Bore, mm	106.5
Stroke, mm	127.0
Connecting rod length, mm	203.0
Compression ratio	17.0:1.0
Maximum power, kW	66.5 at 2200rpm

Control Test

To enable comparison of the engine performance of the PKO Biodiesel with petroleum based (fossil) diesel, similar engine performance tests were conducted for low sulphur petroleum-based diesel purchased at TOTAL fuel station, Ifo, Nigeria.

History of the PKO Biodiesel Fuel used

The palm kernel oil biodiesel used was produced by Alamu (2007) [11] at the Laboratory of the College of Engineering, Olabisi Onabanjo University, Ibogun, Nigeria. The fuel was produced through transesterification process using 100g PKO, 20.0% ethanol (wt% PKO), 1.0% potassium hydroxide catalyst at 60°C reaction temperature and 90 min. reaction time. The biodiesel was characterized as alternative diesel fuel through series of ASTM standard fuel tests. The transesterification process yielded 95.4% PKO biodiesel. The PKO biodiesel had 85.06% reduction of viscosity over its raw vegetable oil at 40°C. The fuel has higher specific gravity, pour point, and cloud point compared to that of commercial grade petroleum diesel as presented in Table 2. The values compare favourably with results for other vegetable oil biodiesel and were within international biodiesel standards limits. [10]

Table 2. Properties of PKO biodiesel fuel used [17]

Fuel characteristics	PKO-biodiesel	Petroleum diesel
Viscosity (at 40°C) (cSt)	4.839	2.847
Specific gravity (at 60°F/60°F)	0.883	0.853
Pour point (°C)	2	-16
Cloud point (°C)	6	-12
Flash point (°C)	167	74
Gross heat of combustion (MJ/kg)	40.56	45.43
Net heat of combustion (MJ/kg)	37.25	42.91

Results

Results of the torque and power test carried out on diesel engine fueled with the PKO biodiesel and the petroleum diesel are as presented in Table 3. This provides some baseline for assessment of the short term performance of diesel engine running on PKO biodiesel against acceptable standards.

Table 3. Engine performance test

Diesel engine rpm	PKO biodiesel		Petroleum-diesel	
	Power (kW)	Torque (kW)	Power (kW)	Torque(kW)
1300	37.0	280	39.0	290
1500	45.0	288	48.0	300
1700	52.0	288	55.0	305
2000	57.5	270	62.0	290
2250	58.0	245	64.0	260
2500	60.0	230	65.0	240

Discussion

Torque characteristics

Figure 1 shows a graphical comparison of the torque output of the test engine for the PKO biodiesel fuel and the reference petroleum diesel tested. It is observed that at all the engine speed tested, torque output for the PKO biodiesel are generally lower than those for the petroleum diesel. Similar observations have been reported for waste french-fry oil and low sulphur No. 2 diesel fuel [14,15].

From Fig.1, there was a relative reduction of 3.45, 4.0, 5.57, 6.89, 5.77% and 4.17% at 1300, 1500, 1700, 2000, 2250 and 2500rpm respectively for the PKO biodiesel. This

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observation was obviously responsible for the flatter curve obtained for the torque output for the PKO biodiesel fuel compared to the conventional petroleum based diesel used as reference diesel fuel. It is also observed that the peak value of torque (288Nm) obtained for the PKO biodiesel fuel occurred at 1500rpm. This engine speed is lower than the 1700rpm where the torque output for the petroleum diesel peaked (305Nm). These observations were found to be consistent with earlier findings reported by a number of authors [12-15].

These authors indicated that peak torque was less for the ester fuels than for diesel, but occurred at lower engine speed and generally the torque curves were flatter. For ethyl and methyl esters of canola, rapeseed, soybean oils and beef tallow, at 1700rpm, the torque reduced 5% while at 1300rpm, it reduced only 3% [15]. For hydrogenated soy ethyl ester at 1700rpm, the torque reduced 6% while at 1300rpm it reduced only 3.2% [14].

Power characteristics

From Table 3, the power curves for the PKO biodiesel fuel and the reference conventional petroleum diesel tested were plotted in Figure 2. It is observed from the curves that less power output is obtained from the PKO biodiesel compared to the petroleum diesel.

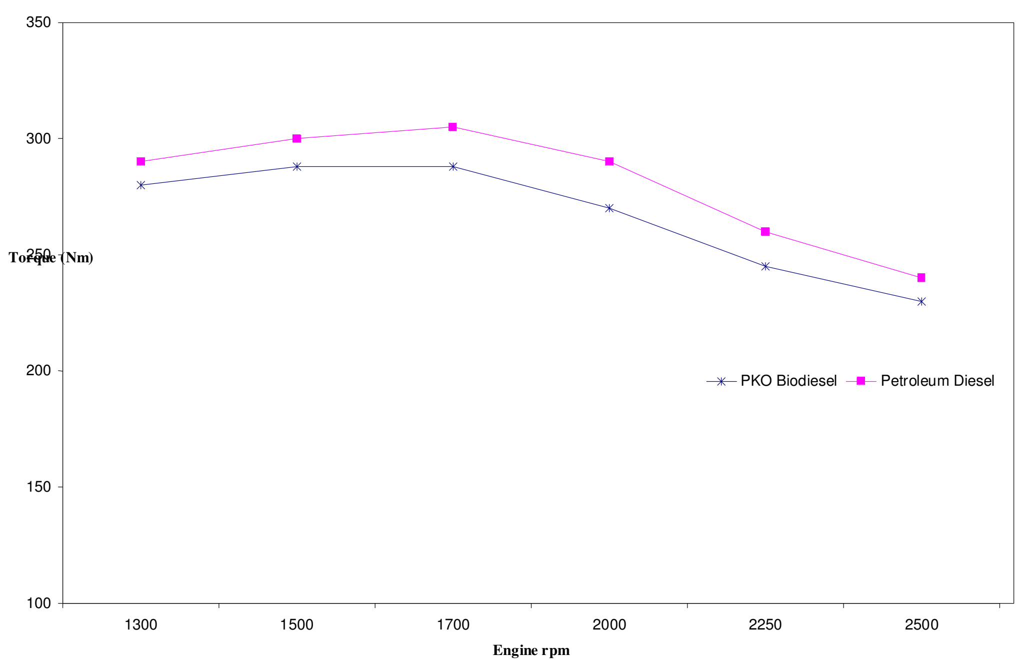

***Figure 1**. Torque curve for PKO biodiesel fuel and petroleum diesel tested*

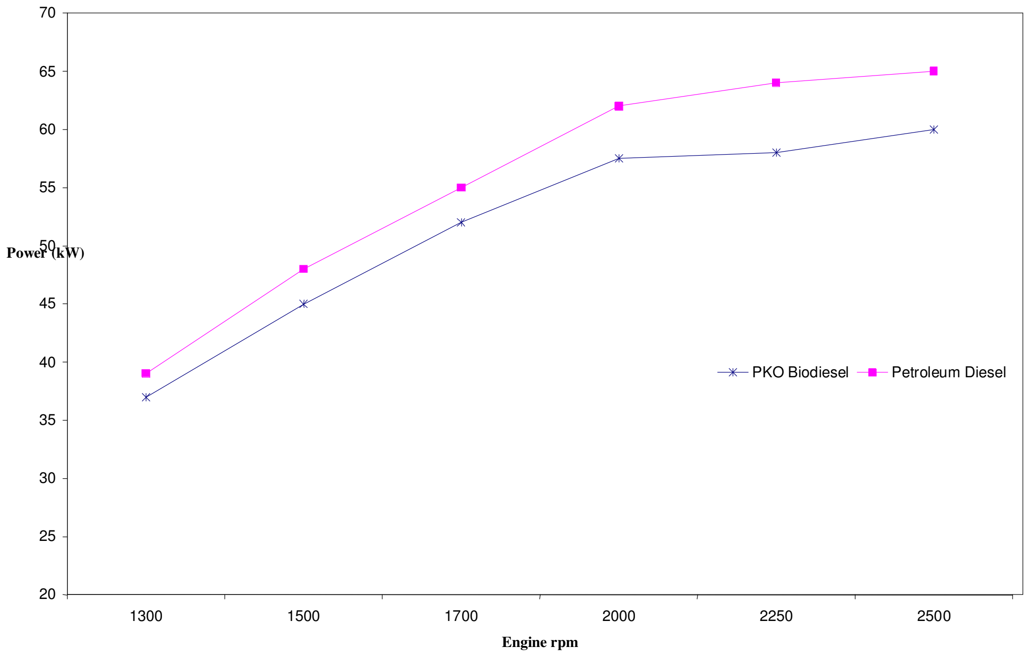

Figure 2*. Power curve for PKO biodiesel fuel and petroleum diesel tested*

Table 4. Comparison of power output for PKO biodiesel with petroleum diesel

Diesel engine speed (rpm)	Relative decrease in power output for PKO biodiesel (%)
1300	5.128
1500	6.250
1700	5.455
2000	7.258
2250	9.375
2500	7.692

The percentage decrease in power observed in the PKO biodiesel relative to the petroleum diesel at the various engine speeds considered, evident from Fig.2, are as tabulated in Table 4.

Conclusions

The limited performance tests carried out showed that PKO biodiesel can successfully fuel a diesel engine. Specifically, the following conclusions can be drawn:

i) At all the engine speed tested torque outputs for PKO biodiesel are generally lower than those for petroleum diesel.

ii) Peak torque (288Nm) obtained for PKO biodiesel occurred at a lower engine speed (1500rpm) compared to petroleum diesel with 305Nm peak at 1700rmp.

iii) Less power output are obtained from the PKO biodiesel compared to the petroleum diesel.Text for this section.

References

1. Ibrahim, A.M., Nassib A.M., Abdel-Hafz O.M., Bady M.F. *A study of the performance and exhaust emissions of spark ignition engine fuelled by ethanol-gasoline blends*, Proceedings 3rd International Conference on Heat Powered Cycles, Cyprus, October 2004.
2. Umar Garba M., Al Hassan M., Kovo, A.S. *A review of advances and quality assessment of biofuels*, Leonardo Journal of Sciences, 9: 167-178, 2006.
3. Gupta P.K., Kumar R., Panesar B.S., Thapar V.K., *Parametric studies on bio-diesel prepared from rice bran oil*, Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, IX(EE 06 007), 2007.
4. Peterson C.L., Cruz R.O., Perkings L., Korus R., Auld D.L., *Transesterification of vegetable oil for use as diesel fuel*: *A progress report*., 1990, ASAE Paper No. 90-610.
5. Noureddini H., Zhu D., *Kinetics of transesterification of soybean oil*. J. Am. Oil Chem. Soc., 74(11):1457 – 63, 1997.
6. Abigor R.D., Uadia P.O., Foglia T.A., Haas M.J., Jones K.C., Okpefa E., Obibuzor J.U., Bafor M.U., *Lipase-catalysed production of biodiesel fuel from some Nigerian lauric oils*. Biochem Soc Trans, 28:979–81, 2000.
7. Darnoko D., Cheryan M., *Kinetics of palm oil transesterification in a batch reactor* JAOCS, 77(12): 1263 – 1267, 2000.
8. Chitra P., Venkatachalam P., Sampathrajan A., *Optimisation of experimental conditions for biodiesel production from alkali-catalysed transesterification of Jatropha curcus oil*, Energy for Sustainable Development, IX(3):13-8, 2005.

9. Ugheoke B.I., Patrick D.O., Kefas H.M., Onche E.O., *Determination of optimal catalyst concentration for maximum biodiesel yield from Tigernut (cyperus esculentus) oil*. Leonardo Journal of Sciences, 10:131-136, 2007.
10. Alamu O.J., Waheed M.A., Jekayinfa S.O., *Biodiesel production from Nigerian palm kernel oil: effect of KOH concentration on yield*, Energy for Sustainable Development, XI(3): 77-82, 2007.
11. Alamu O.J., *Development and evaluation of palm kernel oil biodiesel fuel*, The Pacific Journal of Science and Technology8 (2): 212-215, 2007.
12. Peterson C. L., Reece D.L., *Emmissions tests with an on-road vehicle fuelled with methyl and ethyl esters of rapeseed oil,* ASAE Paper No.946532, ASAE, St.Joseph. MI, 1994.
13. Korus R. A., Hoffman D. S., Bam N., Peterson C.L., Drown, C. D., *Transesterification process to manufacture ethyl ester of rape oil,* Report from Department of Chemical Engineering, University of Idaho, Moscow, ID 83843, 1995.
14. Peterson C.L., Reece D.L., Hammond B.C., Thompson J.C., Beck S, *HYSEE preliminary processing and screening,* A Project report of Department of Agricultural Engineering, University of Idaho presented to Idaho Department of Water Resources, 1995.
15. Peterson C.L., Reece D.L., Hammond B.C., Thompson J.C., Beck, S., P*roduction and testing of ethyl and methyl esters,* A Report of Department of Agricultural Engineering, University of Idaho, 1995.
16. Singh R.N., Singh S.P., Pathak B.S. (2007) *Performance of renewable fuel based CI engine*, Agricultural Engineering International: the CIGR Journal of Scientific Research and Development, Paper No. EE 0014 Vol. IX, 2007.
17. Alamu O.J, Waheed M.A., Jekayinfa S.O., *Effect of ethanol-Palm kernel oil ratio on alkali-catalysed biodiesel yield*, Fuel, 87(8-9):1529-1523, 2008.