Alexandria Engineering Journal (2015) **54**, 389–393

HOSTED BY

ELSEVIER

Alexandria University

Alexandria Engineering Journal

www.elsevier.com/locate/aej
www.sciencedirect.com

ORIGINAL ARTICLE

Emission and Performance analysis of hydrotreated refined sunflower oil as alternate fuel

J. Hemanandh *, K.V. Narayanan

Department of Mechanical Engineering, Sathyabama University, Chennai, India

Received 28 December 2014; revised 1 April 2015; accepted 5 April 2015
Available online 28 April 2015

KEYWORDS

Hydrotreatment;
Refined sunflower oil;
DI diesel engine;
Emission and performance

Abstract The experiments were conducted by using the hydrotreated refined sunflower oil as alternative fuel in a 4-stroke, stationary DI diesel engine at a constant speed of 1500 rpm. The effects of hydrotreated vegetable oil blends on diesel engine emission and performance were studied. The emission and performance were studied for different proportions such as HTSF B25 and HTSF B100 and at different loading conditions and comparison was made with petrodiesel. The emission and performance results of HTSF B25 and HTSF B100 showed that decrease in CO by 9% and 37%, HC by 42% and 55%, NO_x by 10% and 18.18%, BSFC by 25% and 12.5%. The increase in brake thermal efficiency was by 10% and 38%. It was observed from the study that hydrotreatment of refined sunflower oil could be one of the best alternative fuels for the diesel engine.

1. Introduction

In India, energy crisis, though not yet assumed alarming proportions, has started causing concerns because of burgeoning population, fast depleting fossil fuels, and increase in environmental pollution which have forced us to look for an alternative fuel. Atadashi et al. [1] showed that by using membrane separate technique they could remove the potassium catalyst from palm oil biodiesel using transesterification. Further they optimized the temperature, flow rate and the transmembrane pressure in order to reduce the amount of potassium. Basha et al. [2] experimented with the jatropha methyl ester emulsion blended with carbon nanotubes at different proportions to effect an increase in brake thermal efficiency and decrease in peak cylinder pressure. EL_Kassaby et al. [3] investigated by varying the compression ratio from 14 to 18 in the diesel engine with the transesterified waste cooking oil being the fuel. The result showed an increase in brake thermal efficiency, NO_x, CO_2, whereas a decrease in CO, HC. Hansdah et al. [4] produced bioethanol from Madhuca Indica flower and blended with diesel fuel at different proportions. The blend was tested in the 4.5 kW diesel engine. Longer ignition delay, decrease in NO_x, smoke, and improved performance were the results. Gopal et al. [5] observed that using waste cooking oil had similar properties as diesel. The CO, unburnt hydrocarbon, smoke, and brake thermal efficiency decreased, whereas there was an increase in NO_x and specific fuel consumption. Heikkilä et al. [6] studied the performance by adjusting the intake valve closure timing and start of injection using hydrotreated vegetable oil compared with fossil diesel fuel. The result showed reduction in NO_x and particle size at all loads. Liu et al. [7] produced the biohydrogenated diesel and liquid

* Corresponding author.

Peer review under responsibility of Faculty of Engineering, Alexandria University.

http://dx.doi.org/10.1016/j.aej.2015.04.004
1110-0168 © 2015 Faculty of Engineering, Alexandria University. Production and hosting by Elsevier B.V.

Nomenclature

PD	pure diesel	HC	hydrocarbon
HT SF B25	25% hydrotreated sunflower oil + 75% pure diesel blend	CO_2	carbon-di-oxide
HT SF B100	100% hydrotreated sunflower oil	NO_x	nitrogen oxide
CO	carbon monoxide	BSFC	brake specific fuel consumption
		BTE	brake thermal efficiency

petroleum gas from the palm, canola, and jatropha vegetable oil using Ni–Mo/SiO_2 as catalyst. The vegetable oil was converted into paraffins and used as a fuel in the diesel engine. Imperato et al. [8] studied the performance and emission characteristics of the hydrotreated vegetable oil in the medium speed large bore engine. The valve timing and injection parameters were tuned and tested with the hydrotreated oil. The engine was tuned and the NO_x emission was reduced. Murtonen et al. [9] used EN590 diesel fuel, FAME, HVO, and GLT fuels in the diesel engine and the results showed that NO_x emission was high in FAME when compared with HVO and GTL. The other emissions were reduced compared with EN590 diesel fuel. Karonis et al. [10] used the hydroprocessed used cooking oil blended with EN590 diesel fuel displaying the cold flow properties and this improved the low quality cetane diesel resulting in better performance. Heuser et al. [11] converted the Crude Tall Oil into renewable diesel fuel using hydrotreatment process. The 30% of renewable diesel was blended with diesel and tested in the diesel engine. The results showed that the performance and emission were the same in comparison with diesel fuel. Lehto et al. [12] focused on miller cycle and exhaust gas recirculation. In miller cycle, the engine inlet valve close timing and the start of injection timing were varied. The hydrotreated fuel was tested in this condition and compared with EN590 diesel fuel and reported a reduction in NO_x. Bhardwaj et al. [13] tested the hydrotreated rape seed oil in the diesel engine and compared with diesel fuel. The results showed reduction in CO, HC, and soot.

The aim of the work was to reduce the emissions and improve the performance of the diesel engine using hydrotreated refined sunflower oil as diesel fuel. The emission and performance of the diesel engine were studied.

2. Materials and methods

The Sunflower oil was procured from the local dealer. The experiments were conducted in two phases. Phase I: The Refined sunflower oil was hydrotreated. Phase II: The hydrotreated oil was tested in the diesel engine. The emission and performance were analyzed with diesel.

2.1. Preparation of hydrotreated refined sunflower oil

The refined sunflower oil was used as a feed. The feed was treated with high pressure-trickle bed reactor. The capacity of the tubular reactor was of a volume of 400 ml. The Ni–Mo/Al_2O_3 catalyst was used. By using standard procedure the catalyst was dried and sulfided using diesel spiked with Dimethyl Disulfide (DMDS). The refined sunflower oil was preheated and treated with hydrogen gas. The sunflower oil was preheated and treated with hydrogen gas at temperature of 360 °C and a pressure of 60 bar.

The various reactions took place and n-alkanes were formed. The n-alkanes were converted into isoalkanes with the isomerization catalyst. The triglycerides were converted into propane. This could be observed in increase in cetane number. The hydrotreated vegetable oil has C-17 and C-18 for refined sunflower oil for 29% and the presence of C-18 shows the deoxygenation in the initial reaction. The deoxygenation absorbs more hydrogen than the decarboxylation reaction. The feed and the green diesel are shown in Figs. 1 and 2. There was increase in calculated cetane index, Flash point, and the calorific value, whereas lowering in density and kinematic viscosity were observed as given in Table 1 and compared with Euro Bharat stage-IV (see Table 2).

2.2. Experimental set-up

The green diesel was tested in the stationary, vertical, 4S DI diesel engine to analyze the performance and emission of the diesel engine. The engine was tested for various loading conditions at a constant speed of 1500 rpm. The engine was coupled with an alternator and the eddy current was used to load the engine in steps of 25%. The different loading conditions were 0%, 25%, 50%, 75%, and 100%. The hydrotreated green

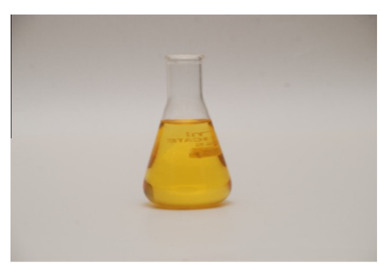

Figure 1 Refined sunflower oil.

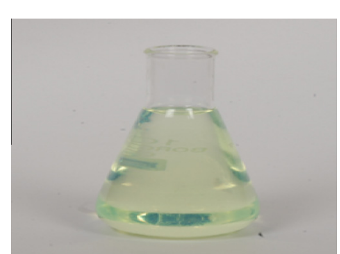

Figure 2 Hydrotreated oil.

Table 1 Comparison of properties of diesel, biodiesel standards and HTSFO.

S. No.	Properties	Euro-IV Bharat stage 1460:2005 diesel fuel	ASTM D-751 (IS 5607:2005)	Refined sunflower oil (feed)	HTSFO (product)
1.	Calculated cetane index	51	–	35	81
2.	Density at 15 °C kg/m^3	820–845	860–900	922.5	798.8
3.	Kinematic viscosity at 40 °C cSt	2–4.5	1.9–6	28.3	3.69
4.	Flash point °C min	35 °C	130 °C	254	64.5
5.	Calorific value kJ/kg	39,000	–	38,796	43,754

Table 2 Specification of test engine.

Type	Vertical, 4S, high speed CI diesel engine
Combustion	Direct injection
Rated power	4.3 kW
Rated speed	1500 rpm
Compression ratio	17.5:1
Injector type	Single 3 hole jet injector
Fuel injection pressure	210 bar
Dynamometer	Eddy current

diesel was prepared in different proportions such as HTSF B25 and HTSF B100 and tested in the engine. For every proportion of oil blend, the engine was allowed to run for 15 min for each proportion before loading and the average of 3 tests was recorded. The emissions (CO, HC, and NO_x) and the smoke were measured using an AVL DIGAS 444 Analyzer and the AVL smoke meter. The schematic set-up of the compression ignition engine is shown in Fig. 3.

3. Results and discussions

3.1. Carbon monoxide (CO)

The CO emissions of the hydrotreated sunflower oil are shown in Fig. 4. The comparison between the HTSF B25 and HTSF B100 was done with reference to petrodiesel. It can be observed from the graph that HTSF B25 is the same as diesel up to 75% of the load, whereas it decreases at full load condition by 9%. HTSF B100 decreases by 37% at full load condition. This might be due to the higher calculated cetane index facilitating better combustion.

3.2. Hydrocarbon (HC)

The emission of HC is shown in Fig. 5. The HC emission reduces in HTSF B25 and HTSF B100 by 42% and 55%

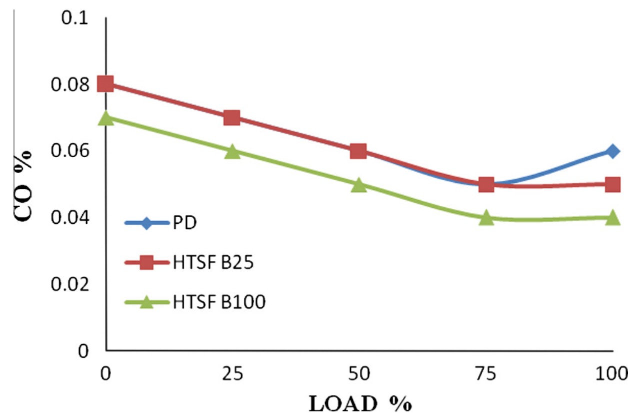

Figure 4 Comparison of CO emission for HTB25 and HTB100 with diesel.

respectively at full load condition and at a constant speed of 1500 rpm. This could be due to the higher hydrogen content in the fuel which enhances better combustion when compared with diesel fuel. The hydrotreated seed oil and animal waste fat can produce high paraffins and this reduces the HC [13].

3.3. Nitrogen oxides (NO_x)

Fig. 6 shows NO_x emissions of the Hydrotreated Refined sunflower vegetable oil and diesel fuel. The NO_x is formed due to increase in combustion temperature. The NO_x is reduced for HTSF B25 by 10% and HTSF B100 by 18.18%. This might be due to the flame characteristics of the hydrotreated vegetable oil causing reduction in the flame temperature.

3.4. Brake specific fuel consumption (BSFC)

The brake specific fuel consumption (BSFC) of the hydrotreated refined sunflower oil at different loads is compared

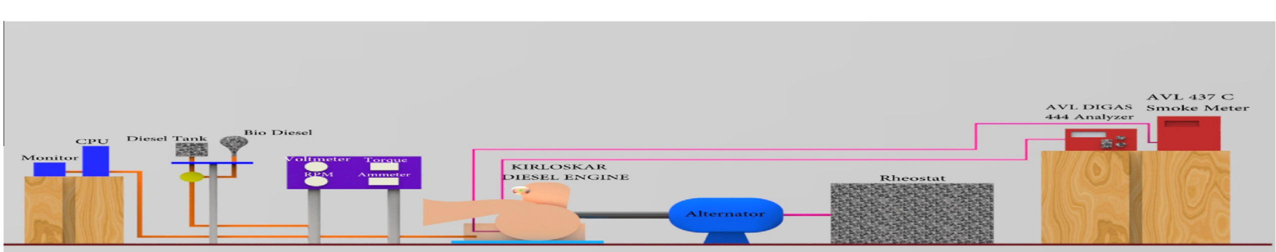

Figure 3 Schematic set-up of the compression ignition engine.

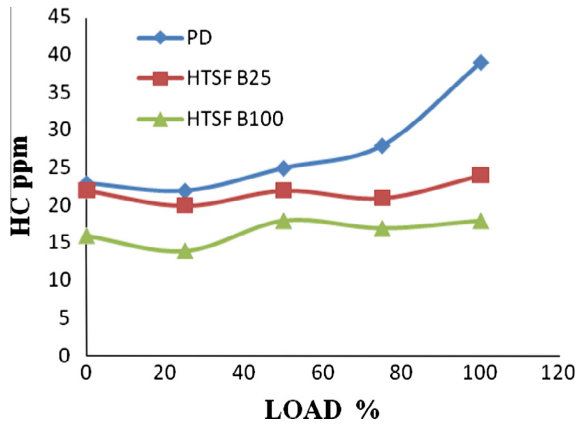

Figure 5 Comparison of HC emission for HTB25 and HTB100 with diesel.

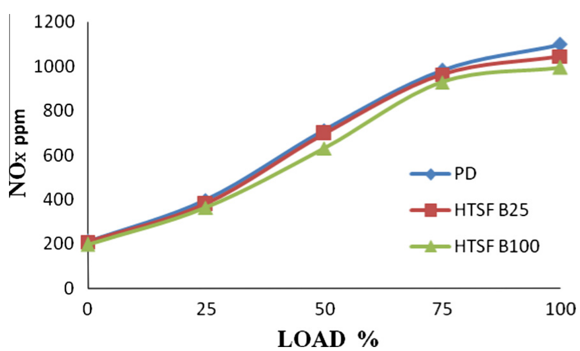

Figure 6 Comparison of NO_x emission for HTB25 and HTB100 with diesel.

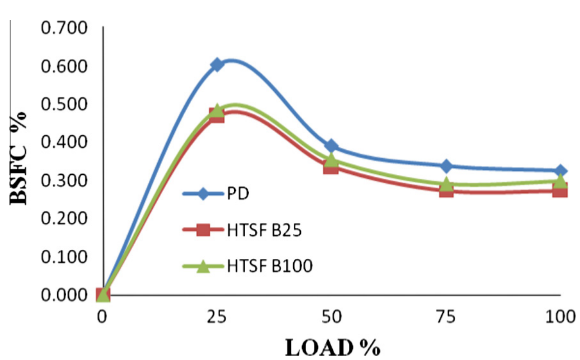

Figure 7 Comparison of BSFC emission for HTB25 and HTB100 with diesel.

with petrodiesel as shown in Fig. 7. From the graph, it can be seen that the fuel injection to the engine is decreased for HTSF B25 and HTSF B100 at full load condition compared with the petrodiesel. HTSF B25 and HTSF B100 decrease by 25% and 12.5% respectively compared with diesel fuel. This might be due to the lower density of the hydrotreated fuel.

3.5. Brake thermal efficiency (BTE)

Fig. 8 shows the comparison of hydrotreated vegetable oil blends and petrodiesel. The brake thermal efficiency of the

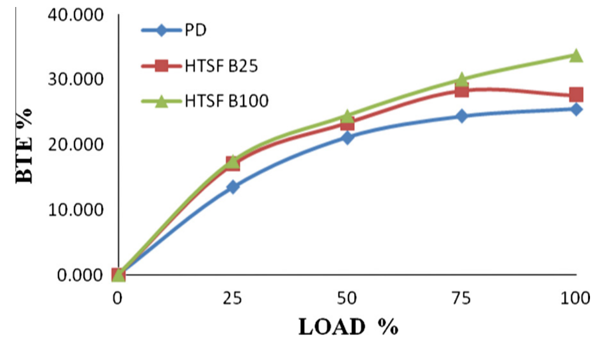

Figure 8 Comparison of BTE emission for HTB25 and HTB100 with diesel.

hydrotreated vegetable oil is greater than that of petrodiesel. It is evident from the graph that the brake thermal efficiency of HTSF B25 and HTSF B100 increases up to 10% and 38% compared with petrodiesel. This could be due to the higher calorific value and the high calculated cetane index of the hydrotreated vegetable oil.

4. Conclusion

The aim of the work was to reduce the emissions from the diesel engine. The hydrotreated refined sunflower oil as biodiesel has been found to be a suitable alternative fuel for diesel engine. The results show that the emissions can be reduced by using hydrotreated refined sunflower oil. A number of tests were conducted for different blends, different loadings and at a constant speed of 1500 rpm. The findings are based on full load condition when compared with petrodiesel.

1. The CO emission decreases for HTSF B25 and HTSF B100 by 9% and 37%.
2. The emissions of HC decrease for HTSF B25 and HTSF B100 by 42% and 55% respectively.
3. The NO_x emission decreases for HTSF B25 and HTSF B100 by 10% and 18.18%.
4. The BSFC decreases in HTSF B25 and HTSF B100 by 25% and 12.5% respectively.
5. There is an increase in brake thermal efficiency for HTSF B25 and HTSF B100 by 10% and 38%.

Acknowledgments

The authors would like to thank the Chennai petroleum Corporation Limited, a Government of India Research Organization, for providing the opportunity to conduct the experiments in their pilot plant for hydrotreatment of oils.

References

[1] I.M. Atadashi, M.K. Aroua, A.R. Abdul Aziz, N.M.N. Sulaiman, Removal of residual palm oil-based biodiesel catalyst using membrane ultra-filtration technique: an optimization study, AEJ 53 (2014) 705–715.

[2] J.Sadhik Basha, R.B. Anand, Performance, emission and combustion characteristics of a diesel engine using Carbon Nanotubes blended Jatropha Methyl Ester Emulsions, AEJ 53 (2014) 259–273.

[3] Mohammed EL_Kassaby, Medhat A. Nemit_allah, Studying the effect of compression ratio on an engine fueled with waste oil produced biodiesel/diesel fuel, AEJ 52 (2013) 1–11.
[4] Dulari Hansdah, S. Murugan, L.M. Das, Experimental studies on a DI diesel engine fueled with bioethanol-diesel emulsions, AEJ 52 (2013) 267–276.
[5] K.Nantha Gopal, Arindam Pal, Sumit Sharma, Charan Samanchi, K. Sathyanarayanan, T. Elango, Investigation of emissions and combustion characteristics of a CI engine fueled with waste cooking oil methyl ester and diesel blends, AEJ 53 (2014) 281–287.
[6] Juha Heikkilä, Matti Happonen, Timo Murtonen, Kalle Lehto, Teemu Sarjovaara, Martti Larmi, Jorma Keskinen, Annele Virtanen, Study of Miller timing on exhaust emissions of a hydrotreated vegetable oil (HVO) – fueled diesel engine, J. Air Waste Manage. Assoc. 62 (2012) 1305–1312.
[7] Yanyong Liu, Rogelio Sotelo-Boyás, Kazuhisa Murata, Tomoaki Minowa, Kinya Sakanishi, Hydrotreatment of vegetable oils to produce bio-hydrogenated diesel and liquefied petroleum gas fuel over catalysts containing sulfided Ni–Mo and solid acids, Energy Fuels 25 (2011) 4675–4685.
[8] Matteo Imperato, Aki Tilli, Teemu Sarjovaara, Martti Larmi, Large-bore compression-ignition engines: high NOx reduction achieved at low load with hydro-treated vegetable oil, SAE Int. J. Fuels Lubr. 5 (2012) 225–232.
[9] T. Murtonen, P. Aakko-Saksa, M. Kuronen, S. Mikkonen, K. Lehtoranta, Emissions with heavy-duty diesel engines and vehicles using FAME, HVO and GTL fuels with and without DOC + POC after treatment, SAE Int. J. Fuels Lubr. 2 (2010) 147–166.
[10] D. Karonis, D. Chilari, C. Manou, Characterization of hydroprocessed used cooking oils in blend with low quality gasoil samples, SAE Int. J. Fuels Lubr. 7 (2014) 250–262.
[11] B. Heuser, V. Vauhkonen, S. Mannonen, H. Rohs, et al, Crude tall oil-based renewable diesel as a blending component in passenger car diesel engines, SAE Int. J. Fuels Lubr. 6 (2013) 817–825.
[12] K. Lehto, A. Elonheimo, K. Häkkinen, T. Sarjovaara, et al, Emission reduction using hydrotreated vegetable oil (HVO) with miller timing and EGR in diesel combustion, SAE Int. J. Fuels Lubr. 5 (2012) 218–224.
[13] O. Bhardwaj, A. Kolbeck, T. Kkoerfer, M. Honkanen, Potential of hydrogenated vegetable oil (HVO) in future high efficiency combustion system, SAE Int. J. Fuels Lubr. 6 (2013) 157–169.