Energy 65 (2014) 101–108

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

# Possibility of using biodiesel from sunflower oil as an additive for the improvement of lubrication properties of low-sulfur diesel fuel

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ARTICLE INFO

*Article history:*
Received 19 April 2013
Received in revised form
10 December 2013
Accepted 14 December 2013
Available online 7 January 2014

*Keywords:*
Biodiesel
Fossil diesel
EN 590
Lubrication properties
Engine performance
Exhaust gas emissions

ABSTRACT

Harsh requirements regarding the exhaust gases emission have conditioned the development of new systems in the engine, as well as the development of ecological fuels. Sulfur extraction considerably impairs the lubrication properties of diesel fuel. This has consequences in the rapid wear of the elements that constitute the fuel injection system. Additives for the improvement of lubrication properties are added with the aim of eliminating the adverse effect of fuel. The problem related to the use of those additives lies in the fact that they contain heavy aromatic solvents such as methyl naphthalene, methyl naphthalene and biphenyl which are harmful to health. Therefore, the aim of this research is to determine whether there is a possibility to use biodiesel for the improvement of lubrication properties of fossil diesel with low sulfur content instead of standard additives.

In this research biodiesel obtained from sunflower oil was blended with fossil diesel which did not have additionally added additives for the improvement of lubrication properties. The obtained results were compared with the other researches on the use of fossil diesel with added standard additives. The blends of fossil diesel and biodiesel content of 1–7% v $v^{-1}$ were used here. The experimental research used different test fuels for the testing of chemical and lubrication properties of fuel, tractor engine performance and exhaust gas emissions.

By adding biodiesel, fossil diesel properties remained within the limits set by the standard EN 590 while lubrication properties were significantly improved. On the other hand, power of tractor engine did not change significantly. Although biodiesel had lower heating value with respect to fossil diesel, blending 5, 6 and 7% v $v^{-1}$ of biodiesel caused slight increase in the engine power. Tests of exhaust gas emissions indicated that the addition of biodiesel reduced the content of $CO_2$ and CO. The problems related to the use of biodiesel as an additive can be reduced by oxidation fuel stability, increased specific fuel consumption, reduced thermal efficiency and increased $NO_x$ emission.



## 1. Introduction

Combustion products occur as the result of fuel combustion in diesel engine. Although most of those products are harmless to people's health, their emission is high due to the extensive use of fuel in the world. Certain norms that define the acceptable limits for exhaust gas emission from the vehicles have been adopted in order to reduce the emission of harmful gases. In order for the set norms to be conformed to, it is necessary not only to develop new technologies which would be applied to diesel engines but also to establish and define the standards of fuel quality. EU Directives have introduced the specifications of 'ecological' fuels set by CEN (*European Standards Organization*). Directive *2009.01* is currently in force and it specifies the maximum sulfur content of 10 mg $kg^{-1}$ for fossil diesel used by vehicles on highways and off-road vehicles. On the other hand, lowered sulfur content caused the problems related to the lubrication of the parts that constitute the fuel injection system [1]. Namely, the technological procedure of desulfurization removes the present polar bonds useful for their lubrication properties [2]. These problems can be overcome with the addition of additives to fossil diesel fuel so that the lubrication properties could be improved. Additives are, in their composition, a mixture of fat acids and heavy

*Abbreviations:* LSDF, fossil diesel with low content of sulfur – no additives; cLSDF, commercial fossil diesel with low content of sulfur – with conventional additives; BD-1, mixture of LSDF and biodiesel in a ratio of 99:1% v $v^{-1}$; BD-2, mixture of LSDF and biodiesel in a ratio of 98:2% v $v^{-1}$; BD-3, mixture of LSDF and biodiesel in a ratio of 97:3% v $v^{-1}$; BD-4, mixture of LSDF and biodiesel in a ratio of 96:4% v $v^{-1}$; BD-5, Mixture of LSDF and biodiesel in a ratio of 95:5% v $v^{-1}$; BD-6, mixture of LSDF and biodiesel in a ratio of 94:6% v $v^{-1}$; BD-7, mixture of LSDF and biodiesel in a ratio of 93:7% v $v^{-1}$; IBP, initial boiling point; FBP, final boiling point.

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http://dx.doi.org/10.1016/j.energy.2013.12.033

aromatic solvents. The use of additives is problematic because they contain a wide range of hazardous components (15–25% heavy aromatic solvents, 1–3% 1 methyl naphthalene, 1–3% 2 methyl naphthalene and 1–2% biphenyl) which are extremely dangerous when inhaled or in contact with skin [3]. Thus, the aim of this study is to investigate the possibilities of use of biodiesel from sunflower oil as a non-toxic additive used for the improvement of the lubrication properties of fossil diesel fuel.

Biodiesel is composed of fatty acid methyl ester obtained by the transesterification of vegetable oils or animal fats. Numerous researches have shown the advantages of biodiesel over fossil diesel fuel. The performances of the engines using biodiesel are similar to those using fossil diesel [4]. However, analyzed performances of the engine using biodiesel from sunflower oil have shown minimum reduction in power with a slight increase of specific fuel consumption [5]. Other researches on the blending of biodiesel, made from sunflower oil, with fossil diesel indicate that regardless of the fact that biodiesel has lower heating value its blending in smaller quantities contributes to an increase of power and torque of the engine at full and partial load. The highest power was achieved by adding 17.5% biodiesel [6]. Use of biodiesel does not require any changes of the engine or the system for fuel injection [7].

The results of researches available in the literature show contrary opinions about $CO_2$ emissions. While certain authors claim that $CO_2$ emission resulting from biodiesel combustion is within the limits of 20–25%, with regard to fossil diesel combustion [8], the others claim that there is no significant difference in the $CO_2$ emission [9]. Biodiesel reduces smoke particulates by 50% on average. The ignition temperature of biodiesel is about 150 °C which makes it safe for storage and use. Biodiesel does not contain sulfur or aromatic compounds. The research conducted on the engines with built-in Common Real system for injection has demonstrated that the use of biodiesel increases the $NO_x$ concentration in the combustion products which is the result of high oxygen concentration in biodiesel. Catalytic converter treatment, selective catalytic reduction and EGR (exhaust gas) recirculation of smaller amount of combustion products can reduce successfully $NO_x$ emission [10–12]. Biodiesel reduces the emission of CO (30–50%) due to the high concentrations of oxygen and carbon [13].

Furthermore, biodiesel has better lubrication properties than fossil diesel [14]. Comparative researches on the effects of biodiesel from palm and Jatropha oils on the lubrication properties of fossil diesel have shown that low content of biodiesel could satisfy the requirements defined by the standard EN 590 [15].

Considering the results obtained from the previous researches in this field it can be assumed that it is possible to blend biodiesel from sunflower oil with fossil diesel in order to eliminate the use of standard (toxic) additives and improve the lubrication properties. The aim of this paper was to determine whether the conventional additives for improved lubrication substituted by biodiesel would affect physical and chemical characteristics of fossil diesel. Also, the aim was to verify the possibility of use of such fuel in widely used engines. Therefore, the experiment was conducted on a standard tractor engine with power of 48 kW. This type of tractor is widely used (designed for different farming operations) and more than 56% of tractors used in agriculture fall into this category [16].

## 2. Materials and methods

### *2.1. Fuels*

The analysis included blending of biodiesel with fossil diesel in the ratio of 99:1% v $v^{-1}$: methyl ester (BD-1), 98:2% v $v^{-1}$ (BD-2), 97:3% v $v^{-1}$ (BD-3), 96:4% v $v^{-1}$ (BD-4), 95:5% v $v^{-1}$ (BD-5), 94:6 % v $v^{-1}$ (BD-6), 93:7% v $v^{-1}$ (BD-7). Methyl ester (biodiesel) was obtained by transesterification of sunflower oil in methyl alcohol in the presence of NaOH as a catalyst. A domestic hybrid 'Somborac' was used during the testing period. It is a medium late hybrid with the vegetation period of 107–113 days. Its genetic potential for seed yield is 4.6 t $ha^{-1}$. The oil content in seed is 48–51%. Prior to the testing, it was necessary to analyze the conformity of biodiesel properties with the standard EN 14214. The results are presented in Table 1.

**Table 1**
Properties of the used biodiesel (EN 14214).

| Property | Units | Limit | Value |
|---|---|---|---|
| Ester content | % m $m^{-1}$ | Min 96.5 | 99.71 |
| Density at 10 °C | kg $m^{-3}$ | 860–900 | 884 |
| Kinematic viscosity at 40 °C | $mm^{-2}$ $s^{-1}$ | 3.5–5.0 | 3.93 |
| Flash point (Pensky–Martens) | °C | Min 120 | 154 |
| Cold filter plugging point (CFPP) – climate classes C | °C | Max. −5 | −4 |
| Sulfur content | mg $kg^{-1}$ | Max 10 | 0.81 |
| Carbon residue remnant (at 10% distillation remnant) | % m $m^{-1}$ | Max 0.3 | 0.19 |
| Sulfated ash content | % m $m^{-1}$ | Max 0.02 | 0.0 |
| Water content | mg $kg^{-1}$ | Max 500 | 279 |
| Total contamination | mg $kg^{-1}$ | Max 24 | 0.1 |
| Copper band corrosion (3 h at 50 °C) | Class | 1 | 1a |
| Acid value | mg KOH $g^{-1}$ | Max. 0.5 | 0.2 |
| Linolenic acid methyl ester | % m $m^{-1}$ | Max. 12 | 6.31 |
| Polyunsaturated (≥3 double bonds) methyl ester | % m $m^{-1}$ | Max. 1 | <0.02 |
| Methanol content | % m $m^{-1}$ | Max. 0.2 | 0.008 |
| Monoglyceride content | % m $m^{-1}$ | Max. 0.8 | 0.163 |
| Diglyceride content | % m $m^{-1}$ | Max. 0.2 | 0.028 |
| Triglyceride content | % m $m^{-1}$ | Max. 0.2 | 0.065 |
| Free glycerine | % m $m^{-1}$ | Max. 0.02 | 0.0004 |
| Total glycerine | % m $m^{-1}$ | Max. 0.25 | 0.0527 |
| Group I metals (Na + K) | mg $kg^{-1}$ | Max. 5 | 4.708 |
| Group II metals (Ca + Mg) | mg $kg^{-1}$ | Max. 5 | 3.044 |
| Phosphorus content | mg $kg^{-1}$ | Max. 10 | 2.61 |

During the testing we used fossil diesel without added additive for the improvement of lubrication properties of fuel (hereinafter LSDF (fossil diesel with low content of sulfur – no additives)[1]) produced in Novi Sad Oil Refinery. The obtained values were compared with commercial low sulfur fossil diesel (hereinafter cLSDF (commercial fossil diesel with low content of sulfur – with conventional additives)[2]) which contained standard additive for the improvement of lubrication properties.

Laboratory testing of the mentioned blends of LSDF, biodiesel and cLSDF were carried out in accordance with the standard EN 590 (2009).

The heating value was determined according to the standard 774-208 Benzoic Acid Pellet, ASTM D5865–07, with the device LECO AS-350 (LECO Corporation; Saint Joseph, Michigan USA). Biodiesel used in this research had the heating value of 40.348 MJ $kg^{-1}$, while for cLSDF that value was 46.291 MJ $kg^{-1}$. The heating values of the test fuels BD-1, BD-2, BD-3, BD-4, BD-5, BD-6 and BD-7 were 46.235, 46.165, 46.105, 46.045, 45.968, 45.925 and 45.849 MJ $kg^{-1}$, respectively.

### *2.2. Engine and instruments*

#### *2.2.1. Fuel lubrication properties tests*

Evaluation of the lubrication properties of the tested fuels was conducted by high frequency reciprocating rig (HFRR) in compliance with the standards ISO 12156-1:2005 and ISO 12156-2:2005.

[1] LSDF – fossil diesel with low content of sulfur – no additives.

[2] cLSDF – commercial fossil diesel with low content of sulfur – with conventional additives.