Fuel 113 (2013) 650–653

Contents lists available at SciVerse ScienceDirect

Fuel

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

Ethanol containing ethyl esters of fatty acids as perspective environment like fuel

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HIGHLIGHTS

- High power-ecological characteristics of ethyl esters of fatty acids were determined.
- Ethyl esters provide the necessary performance and stability of engine work.
- The engine does not require the fuel injection system modification.
- Ethyl esters characterized by low pollutant emission.

ARTICLE INFO

Article history:
Received 1 April 2013
Received in revised form 7 June 2013
Accepted 11 June 2013
Available online 30 June 2013

Keywords:
Biodiesel
Rapeseed oil
Ethyl esters of fatty acids
Emissions
Engine performance

ABSTRACT

The effect of fatty acid ethyl esters used as biodiesel fuel on power and ecological characteristics of diesel engine work has been studied. It is stated that such ethyl esters produced on the base of rapeseed oil provide the necessary performance of the engine, stability and regularity of engine work as well as the engine does not require the fuel injection system modification. Exhaust gases demonstrate lower CO, CO_2, NO_x and CH contents in comparison with pollutant emissions of methyl esters and mineral diesel fuel. It has been proved that reduction of nitrogen oxide emissions is due precisely to peculiarities of ethyl esters, but not to the ethanol additives.

1. Introduction

Biodiesel has become recently as very attractive fuel due to being produced from renewable biomass resources such as vegetable oils and animal fats, because of its biodegradability and non-poisonousness as well as its low emission profiles [1–3]. Thus, the fuels of the biological source base are as an alternative to the usual petroleum fuels. Now biodiesel is produced as a rule by methanol homogeneous catalytic transesterification of vegetable oils and fats. Such a technology has an advantage of the spontaneously dividing the reaction mixture into biodiesel and glycerol phases, whereas the essential demerits of this technology are the methanol toxicity and its biological non-renewability.

By exchanging the methanol by ethanol such spontaneous dividing does not take place. For phases dividing the stages of surplus ethanol vaporization, of selective precipitants adding must be used or ethanol of high purity (>99%) as reagent ought to apply.

Using of biodiesel substantially reduced emission of non-burned hydrocarbon fragments (HC), carbon monoxide, carbon dioxide, particulate matter, sulfur oxides. At the same time the nitrogen oxides content in exhaust gases has been found to increase [4].

A range of works [5–9] are devoted to comparative analysis of diesel fuel and diesel fuels with biodiesel additives including ternary systems like biodiesel–ethanol–diesel, biodiesel–methanol–diesel. Yilmaz [5] reported that with increase of alcohol concentration in blends, CO and HC emissions increase, while NO_x emission reduced. Besides, methanol blends were found as more effective ones than ethanol blends for reducing CO and HC emissions, while NO_x reduction was found to be achieved for ethanol blends. Klausmeier [6] claims that ethanol contributes to the moderation of combustion temperature and can, thereby, reduce NO_x emissions by 10% or more.

Randazzo and Sodre [7] noticed that the addition of anhydrous ethanol to B20 fuel blend (20 vol.% of biodiesel in mixture with

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http://dx.doi.org/10.1016/j.fuel.2013.06.020

mineral diesel) proved it can be a strategy to control exhaust NO_x and global warming effects through the reduction of CO_2 concentration. However, it may require fuel injection modifications, as it increases CO, HC and particulate matter emissions.

He et al. [8] and Hansen et al. [9] studied the influence of ethanol additive to mineral diesel. They notice that in this case increased fuel consumption can be expected.

Thus, the impact of alcohols such as methanol or ethanol on exhaust gases have been studied by a range of researchers, but the environmental characteristics of ethyl esters of fatty acids used as biodiesel fuel have not been examined.

The aim of the present work is to show the merits of pure ethyl esters of rapeseed oil and their mixtures with mineral diesel as well as to study the influence of ethanol additives to mentioned systems.

2. Experimental

2.1. Biodiesel synthesis

We have developed homogeneous catalytic technology of rapeseed oil transesterification by ethanol which demonstrates the spontaneously dividing the esters and glycerol phases [10,11]. KOH (1.5 wt.% of reaction mixture) has been used as the catalyst at 20–50 °C and atmospheric pressure, reaction time up to 1 h, molar ratio ethanol/oil is equal 6–10, ethanol of special preparation and non-refined rapeseed oil have been used.

Product has been manufactured on the pilot plant in the quantities of 400 liters. The rapeseed oil conversion was near 100%, whereas content of ethyl esters was 97%. The surplus ethanol of 5 vol.% has not been removed, and the product obtained has not been undergone any purification.

The mineral diesel fuel of European standard (cetane number is 52, viscosity at 40 °C is 3.08 mm^2/s, density at 15 °C is 834.7 kg/m^3) has been used for mixtures preparation with ethyl esters synthesized. Such blends include the biodiesel component in quantity of 20, 40, 60, 80 vol.%. Moreover the biodiesel samples with different ethanol content (0.2, 5.0 and 10.0 vol.%) have been prepared.

2.2. Experimental apparatus

Experiments were carried out using two cylinder diesel engine (18 kw, 2.1 dm^3, 16.5 compression ratio) of Russian Federation production.

The optimization of fuel injection timing angle (Θ) into the engine cylinder has been done before testing above-mentioned fuels. Optimization consists in the achievement of maximum effective power at a frequency of crankshaft turns n of 1600 rpm. Experimental studies show that the optimum angle Θ was 23° of crankshaft rotation to top dead centre for both standard fuel oil and for biodiesel with ethanol content up to 5%. This correspondence explains by the identity of cetane number of biodiesel (about 52) and mineral diesel fuel. For biodiesel with 10% ethanol content the optimum angle Θ was 25°, which is due to lower cetane number because of low value of this parameter for ethanol (6 units).

After optimization for each fuel type the series of characteristics have been taken, which consist of an external speed, three load (for n = 1200, 1400 and 1600 rpm) and no load characteristics.

Maximum engine power (N_e), maximum torque (T) and engine efficiency (η_e) have been studied for a range of biodiesel blends. Moreover the composition of exhaust gases has been evaluated. The quantities of CO_2, CO and particulate matter in per cents as well as NO_x and CH-fragments concentration in ppm have been determined.

3. Results and discussion

Laboratory testing of pure biodiesel synthesized shows such characteristics: viscosity at 40 °C is 4.45 mm^2/s; density at 20 °C is 877 kg/m^3; high thermal stability; oxidation stability at 110 °C during 6 h; iodine value is 90. Cetane number of the product satisfies the European standard EN 14214:2003 for the biodiesel of methanol technology.

3.1. Power-ecological characteristics

Figs. 1 and 2 show the power characteristics and emission results for pure mineral diesel fuel in comparison with pure biodiesel and their blends. Fig. 1 shows the maximum values of indicators, whereas Fig. 2 is an average for the series of band-tests, includes diesel operation with external speed characteristic, three load and no load characteristics.

Power characteristics of product synthesized on the background of petroleum diesel characteristics are acceptable ones. So, maximum engine power decreases (Fig. 1) at most by 6.5%, the maximum torque by 3.5%, engine efficiency by 5.0%. At the same time

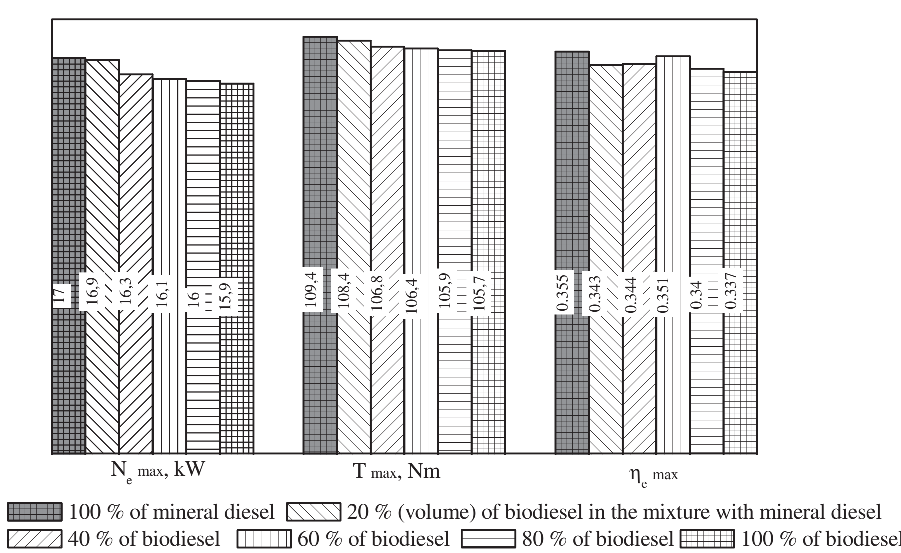

Fig. 1. Power characteristics of pure petroleum diesel, pure biodiesel and their mixtures: $N_e$max – maximum engine power; T_{max} – maximum torque, $\eta_e$max – maximum engine efficiency.