Energy 123 (2017) 241–251

Contents lists available at ScienceDirect

Energy

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

Combustion, performance and emissions of a diesel power generator fueled with biodiesel-kerosene and biodiesel-kerosene-diesel blends

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ARTICLE INFO

Article history:
Received 2 October 2015
Received in revised form
6 November 2016
Accepted 30 January 2017
Available online 5 February 2017

Keywords:
Diesel engine
Biodiesel
Generator
Kerosene
Canola oil

ABSTRACT

High percentages of biodiesel blends or neat biodiesel cannot be used in diesel engines due to high density and viscosity, and poor atomization properties that lead to some engine operational problems. Biodiesel was produced from canola oil by transesterification process. Test fuels were prepared by blending 80% of the biodiesel with 20% of kerosene (B80&K20) and 80% of the biodiesel with 10% of kerosene and 10% diesel fuel (B80&K10&D10). Fuels were used in a 4 cylinders diesel engine that was loaded with a generator. Combustion, performance and emission characteristics of the blend fuels and D2 in the diesel engine for certain loads of 3.6, 7.2 and 10.8 kW output power and 1500 rpm constant engine speed were experimented and deeply analyzed. It was found that kerosene contained blends had quite similar combustion characteristics with those of D2. Mass fuel consumption and Bscf were slightly increased for blend fuels. HC emissions slightly increased while NOx emissions considerably reduced for blends. It was resulted that high percentages of biodiesel can be a potential substitute for diesel fuel provided that it is used as blending fuel with certain amounts of kerosene.

1. Introduction

Researchers maintain their studies on renewable and alternative fuels for IC engines. Vegetable oil based fuels have ever been considered as important fuel option for diesel engines. However, direct use of vegetable oils leads to some problems in engine operation. The reasons of this problem are generally related to high density and viscosity, flow properties and poor volatility of the vegetable oils. Vegetable oil is subjected to the transesterification process and the biodiesel is produced. This process reduces the viscosity and density and improves other fuel characteristics of vegetable oils. Biodiesel has improved fuel properties, such as density, viscosity, flow properties and injection characteristics, etc. However, it still has a higher viscosity and density that exceed the limit values for standard diesel fuel [1,2]. On the other hand, because the surface tension and viscosity of biodiesel is high, it causes poor atomization due to an increase in the mean droplet size of injected fuel jet. High surface tension causes a lowering of the *We*, which represents the secondary deformation of the injected fluid that leads to higher mean droplet sizes of injected biodiesel and eventually leads to poor atomization [3]. The effects of Weber number is found on the secondary deformations after injection when a fluid jet rolling inside another fluid environment such as air etc. low Weber numbers, high density and viscosity will lead technical problems in air-fuel mixture formation due to poor atomization and vaporization and thus longer physical ignition delay. Generally, for a low viscosity fluid, the higher *We* means that the surface tension is lower which provides easy separation of droplets from the fluid body and eventually better atomization. In other words, pure biodiesel or biodiesel-diesel blends with high percentages of biodiesel also have some operational problems in unmodified diesel engines. It has been reported that fuel properties with different biodiesel used in various engine designs result in different combustion behavior. However, biodiesel itself is blended with normal diesel fuel in many cases. Many engine manufacturers only permit the use of biodiesel up to certain limits [4]. Some engine manufacturers approve of up to 20% blends of biodiesel fuel for use in diesel vehicles [5]. Whether the case is the neat biodiesel or

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http://dx.doi.org/10.1016/j.energy.2017.01.153
0360-5442/

Nomenclature

B100	Neat safflower oil biodiesel
BSFC	Brake specific fuel consumption
BTE	Brake thermal efficiency
CAD	Crank angle degree
CHR	Cumulative heat release
CI	Compression ignition
CO	Carbon monoxides
CO_2	Carbon dioxides
D2	Diesel fuel with 50 ppm sulfur content
DEE	Diethyl ether
EGT	Exhaust gas temperature
HC	Unburned hydrocarbon
ID	Ignition delay
HRR	Heat release rate
JP-5	Kerosene based aviation fuel number 5
JP-8	Kerosene based aviation fuel number 8
K100	Neat kerosene
AGT	Average gas temperature
NOx	Nitrogen oxides
NO	Nitric oxide
Pmax	Average peak pressure values of 100 cycles
B80&K20	The blend of 80% of canola oil biodiesel-%20 of kerosene
B80&K10&D10	The blend of 80% of canola oil biodiesel-%10 of kerosene-%10 of diesel fuel
ULSD	Ultra-low sulfur diesel fuel
We	Weber number

its blends with diesel fuel, one of another problem is the increasing of the NOx emissions [6–9].

The problem of using pure or high percentages biodiesel blends could be solved by blending it with another fuel, such as kerosene, that has a lower density, low viscosity, lower distillation temperature and better flow properties. It was reported that treatment with chemical additives is the most convenient and economical way of improving the low-temperature properties of diesel fuels. This technology is also very attractive in biodiesel industries [10]. Even though the cetane number of kerosene is lower, which may cause a longer ignition delay period in the combustion chamber, its lower distillation temperature shortens ignition delay. Bergstrand [11] has reported that kerosene has a lower cetane number than diesel, thus giving a longer ignition delay. If kerosene is just used as fuel additive in biodiesel in order to improve injection characteristics, however the problem of a longer ignition delay will not be faced.

Even though studies of biodiesel, research and development of different types of kerosene-based fuels to adapt them for diesel engines have been conducted [12–16], there are a few studies on kerosene-biodiesel blends in diesel engines. In the present study a more comprehensive analysis, on the effects of a binary blend of biodiesel-kerosene and a ternary blend of biodiesel-kerosene-diesel, was carried out in order to deeply analyze the effects of kerosene.

Effect of ethanol, kerosene and commercial additive on cold flow behavior of this biodiesel was studied [10]. Kerosene addition to biodiesel improved the flow properties and reduced the kinematic viscosity of the fluid. Also NOx was reported to be decreased that was linked to the higher heat of vaporization and lower flame temperature of the kerosene. In other works, it was concluded that the flow properties of the biodiesel, such as kinematic viscosity, cloud point, and pour point were improved with kerosene [17and18].

Considering the combustion and performance change with kerosene addition to a diesel engine fuel, it was reported that the presence of kerosene in the blend leading to better atomization, vaporization, mixture formation and combustion with improved premixed combustion phase. Brake thermal efficiency was also reported to be improved by kerosene addition [19]. Roy et al. [20] studied in this point and found that the bsfc increased with the increasing biodiesel in the biodiesel–diesel-additive and in the blends of biodiesel–diesel. At medium and low load conditions, CO emissions were considerably reduced with both biodiesel–diesel-additive and biodiesel–diesel blends. On the other hand, under all load conditions HC emissions were reported to be significantly decreased with increasing of biodiesel blends, while only under heavy loads kerosene–biodiesel blends led to a reduction in HC. NOx emissions were reduced by using kerosene–biodiesel blends at all load conditions. NOx emissions increase with the increase of biodiesel in the blends under higher loads.

It was tested Arkoudeas et al. [21] that in a single-cylinder diesel engine operating with pure JP-8 and JP-8 fuel blended with 10 vol%, 30 vol% and 50 vol% of sunflower and olive oil. It was reported that using both biofuels reduced PM emissions, but HC and CO emissions did not significantly change with the added biodiesel. NO and NOx emissions decreased at low (10%) biodiesel levels, but the NOx emissions increased at high (50%) percentages of biodiesel in the fuel blend. Another study was conducted on a single cylinder diesel engine at maximum torque speed of 2200 rpm and four loads. JP-8 fuel and sunflower methyl ester blends B25, B50 and B75 showed that NOx emissions increased, but the CO emissions decreased as the amount of biodiesel fuel increased in the test fuels [22]. It can be seen from the above mentioned archival literature that blending kerosene with biodiesel have the potential of eliminating the negative sides (Namely, high density, viscosity and surface tension and increase of NOx emissions) of biodiesel or its high percentages blends with diesel when used as fuel in diesel engines. Combustion of liquid fuels in a diesel engine is a complex phenomenon that is highly depended on the atomization of the fuel spray and vaporization. The thermo-physical properties of fuel influence the combustion performance of liquid fuel spray in diesel engines, which also plays significant roles in controlling the overall combustion performance inside the cylinder. Injection, mixing and thus combustion performance of biodiesel fuel are aimed to be improved by blending with kerosene [23]. The effects of kerosene usage in biodiesel and in biodiesel-diesel blends on the combustion, performance and emissions in a diesel engine have been investigated. The goal of this study was to evaluate the potential usability of high percentages of biodiesel in an unmodified diesel engine. The purpose of using kerosene was to investigate the possibility of using high percentages biodiesel blends in diesel engines. Comprehensive experiments were carried out to clarify the changes in engine test parameters when running it with the kerosene-biodiesel blends. Even though it appears that some works [16and20] has been done on the kerosene usage in diesel engines by blending it with biodiesel, studies are still limited. Therefore the topic in the present work is required to be investigated to succeed the deficiencies in the literature.