Fuel 235 (2019) 723–735

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Emission and injection characteristics of corn biodiesel blends in diesel engine

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ARTICLE INFO

Keywords:
Biodiesel
Pentanol
Diesel engine performance
Emissions

ABSTRACT

In recent years, industries have been investing to develop an alternative fuel to replace the depleting petroleum products which emit higher emission. This paper investigates combustion, performance and emission characteristics of the corn vegetable oil methyl ester with oxygenated additives. Pentanol and titanium oxide are used as additives to increase the efficiency of a diesel engine with reduced emission. A set of experiments are carried out in water cooled multi-cylinder diesel engine at different engine rpm, different engine loads and two different injection pressures. The Diesel, CVOME, CVOME75P20T100, CVOME75P20T200, CVOME75P20T300, CVOME85P10T100, CVOME85P10T200 and CVOME85P10T300 are used as test fuels. The pentanol and titanium oxide nanoparticles are mixed with fuel by ultrasonication process at different ppm. For all testing conditions, biodiesels report the superior results compared to conventional diesel fuel. CVOME75P20 with 5% of titanium dioxide at 300 ppm performs better than other mixture fractions. Results obtained shows that BSFC is improved by 6.3% with CVOME75P20T300 while BP is increased 22% with CVOME75P20T300 compared to diesel at full load condition. Astonishing reductions are seen on CO, HC and smoke emissions with the usage of corn oil biodiesel compared to diesel. Furthermore, 16% reduction in NO_x and particulate emission are reported with CVOME75P20T300.

1. Introduction

In recent ages, one of the serious concerns for all industries and growing countries is energy. Generating energy from the renewable resources like petroleum products and coal is increasing day by day which paves the way to increase the emission of green house gases. This GHG are spoiling the environment by polluting up the world's air. Developing an alternate fuel with less emission has been challenging one for few decades to several pioneers. United States (U.S) department of energy launched a policy called Energy Policy Act, 1992(Epact) to motivate the people to use clean energy and to increase the overall energy efficiency in the U.S [1]. As the oil well is drying up petroleum fuel is likely to go extinct, this leads the nation to face financial crisis and recessions. Similar to roadways, Air transport also depends on petroleum products. Recent days, use of air transport is growing higher. Nearly 5 million barrel oil is consumed by aviation jets. India and China are the two nations which use a maximum amount of aviation fuel due to their dense population. Due to this, global demand will continue to rise in upcoming years. There are several strategies planned by governments around the world to develop a fuel from non conventional modes of energy with less emission, especially the U.S and China. The main desperado of the alternate fuel is emission. The petroleum products are capable of emitting high toxic gases like CO (Carbon monoxide), SO_x (Sulphur oxides), NO_x and other PM (particulate matters) [2]. These gases deplete the ozone layer by increasing the levels of GHG. Several works are proved that GHG has a capability to change the global climate. 25% of the GHG is emitted from automotive vehicles, which should be seriously noted. Statistics show 60% of GHG is emitted by small vehicles, 22% by medium/large vehicles, 8% by Air transport and 4% by water transport and so on. Recently an article released by U.S government stating that 36% of energy consumption of U.S is based on petroleum products which is comparatively higher than India were uses only 23% of petroleum products but it burns coal up to 44% where the U.S only burns 19% of coal. Similar to India, China also burns 66% of coal for generating the energy. So India and China are the serious threats to the world's pollution rate. From the previous literature, it is understood that the major drawback for using vegetable oil is cost and viscosity [3]. The Viscosity of the biodiesel is 10–20 times greater than fossil fuels. On the other hand, using of vegetable oil directly to the IC engine can bring up the issues like fuel filter blockage, incomplete combustion, mass flow rate and poor atomization [4]. Hence the vegetable oil is transformed into biodiesel by transesterification process.

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https://doi.org/10.1016/j.fuel.2018.08.071
Received 4 October 2017; Received in revised form 3 March 2018; Accepted 15 August 2018

Nomenclature

CVOME	Corn methyl ester
CVOME75P20T100	25%Corn methyl ester + 50 Diesel + 20% pentanol + 5% titanium dioxide at 100 ppm
CVOME75P20T200	25%Corn methyl ester + 50 Diesel + 20% pentanol + 5% titanium dioxide at 200 ppm
CVOME75P20T300	25%Corn methyl ester + 50 Diesel + 20% pentanol + 5% titanium dioxide at 300 ppm
CVOME85P10T100	25%Corn methyl ester + 60 Diesel + 10% pentanol + 5% titanium dioxide at 100 ppm
CVOME85P10T200	25%Corn methyl ester + 60 Diesel + 10% pentanol + 5% titanium dioxide at 200 ppm
CVOME85P10T300	25%Corn methyl ester + 60 Diesel + 10% pentanol + 5% titanium dioxide at 300 ppm
BP	brake Power, KW
BSFC	brake specific fuel consumption, g/kWh
CO	carbon monoxide, g/kWh
CO2	carbon dioxide, g/kWh
DI	direct injection
EGT	exhaust gas temperature, ˚C
HC	hydrocarbons, g/kWh
ID	Ignition delay, ms
IP	Injection pressure, bar
ppm	parts per million (volume)
NOx	nitrogen oxides, g/kWh
PM	particulate matter
P	pentanol
RPM	revolution per minute
TiO_2	Titanium dioxide
η_β	brake thermal efficiency
η_V	volumetric efficiency

This method is the most successful and promising method compared to paralysis or blending. Transesterification process improves the properties of fuel for achieving enhanced combustion and excellent atomization. The major worry is the cost of production, since transesterification process involved the chemical and heat input. In addition to that, during the processing, the biodiesel emits the by-product called glycerol, which is harmful to environment [5]. Few researchers concluded that, using of biodiesel does not contribute to the reduction of NO_x emission. They witnessed crude oil based fuel emits less NO_x compared to biodiesel. To overcome that, recent research going in the field of nanofluids and oxygenated additives. Biodiesel is derived from the animal fats, vegetable oils etc. Among numerous types of biodiesel, corn vegetable oil gained a widespread acceptance since it is easily available than mustard, canola and rapeseed. Further, the growing of corn is easier and cheaper than other crops in the US. The price of the corn vegetable oil is acceptable when compared to untaxed diesel fuel. There are plenty of works available on the performance and emission for vegetable oil [6]. However, only a few studies are made on nanofluids and pentanol. This paper concentrates on the addition of oxygenated agents to increase the performance of the engine with a less amount of emission. To eradicate the use of oil, several techniques are initiated, like reformulation and modification of engine design. Biodiesel usually consists of fatty acids. Transesterification process is a famous process [7] used to generate the biodiesel using vegetable oil and animal fat. Generating the fuel from vegetable oil is a promising source of energy for forever. Mohod et al. [8] reported that biodiesels are the best alternative for the diesel fuel. The biodiesels carry inbuilt oxygen content which supports the combustion process similar to diesel. Few researchers claimed using biodiesel on a diesel engine is possible by making few minor changes in existing engine setup [9]. Ahamed [10] proved that the biodiesel is capable of supporting the combustion by local air and fuel mixing due to its chemical stability [10]. Many notable studies proved that adding 20% of biodiesel can decrease the engine emission like HC, CO, CO_2 and Particulate matter (PM) [11]. Tsai [12] demonstrated the experiment on biodiesel, they revealed that using biodiesel on diesel engine increases the emission of toxic compounds which are harmful to humans. To minimize these difficulties, higher blend alcohols such as butanol and pentanol is used in various proportions [13]. Pentanol has a tendency to reduce the emission and elevate the performance of the engine. The alcohols are dispersed with biodiesel to enhance the performance. The mixing can be done using direct blending and fumigation process [14]. The using of alcohol up to 30% on the diesel engine does not require any superior modification. Few studies reported that the use of alcohol with petroleum products decreases the emission marginally, which should be appreciated [15]. It is reported that use of alcohol in fuel may lead to the reduction of viscosity [16]. This disadvantage can be eliminated by preheating the biodiesel up to 80 ˚C. Campos [17] done experiments to calculate the performance of the biodiesel with pentanol and it found that pentanol has the competence to increase the thermal efficiency more than 3 to 5%. Similarly, Li [11] revealed that the addition of pentanol can decrease the emission of GHG. Agarwal [18] investigated the effect of IP on emission and combustion using methyl ester blend on diesel. They concluded, when IP elevated from 170 to 200 bar, BSFC (Brake specific fuel consumption) is reduced and η_β (Brake thermal efficiency) is increased. This discovery stimulated the role of IP on performance. Kumar [20] investigated the effect of Air-Fuel ratio, inlet temperature, Operating temperature, Combustion rate and IP of biodiesel blends and found that, the above parameters are improving the fuel atomization with decreased rate of emission. Sayin [19] carried out a study on fuel distribution and burning rate using diesel engine. They fuelled with canola oil methyl ester (CVOME). The results show that the performance characteristics of the fuel improve when it is blended with CVOME. In addition, they also found use of CVOME compared to diesel exhibits higher BSFC and η_β. The increase in IP on the fuel increases the performance characteristics of the engine along with decreased emission. Canakci [21] disclose that when the IP is dropped the emission of PM and CO is increased except NO_x and CO_2. This occurs only when IP drops below diesel operating pressure. Shehata [26] studied the biodiesel fuelled by soybean under different engine speed. They acknowledged that the BP and BSFC are improved when the biodiesel is blended with soybean. From the literature, it is well understood that, the addition of blend to biodiesel will increase the performance characteristics. At high IP, the fuel droplets are vaporized more quickly than compared to the original IP due to the effect of atomization [12,19]. This can be avoided by proper choosing of combustion cylinder geometry. Further, using of biodiesel does not reduce the emission of NO_x, this can be achieved by adding nanofluids.

The aim of this paper is to discuss the performance characteristics of new novel biodiesel with reduced Nitrogen oxide (NO_x) emission. The corn biodiesel blends are mixed with nanofluids like pentanol (P) and titanium dioxide (TiO_2) to increase the brake power of the fuel with less emission than diesel fuel. There is several notable work done on biodiesel. However, the study of nanofluids to control the emission and performance at high injection pressure (IP) is limited. This paper concentrates on the area of nanofluid to control NO_x and green house gas (GHG) emission. In addition, the role of IP in the performance and emission is studied.

2. Experimental setup and procedures

In the current study, the combustion performance and emission characteristics of a diesel engine is investigated using corn biodiesel fuel blends at different engine loads and rpm. A comprehensive