Fuel xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Experimental studies for the thermo-physiochemical properties of Biodiesel and its blends and the performance of such fuels in a Compression Ignition Engine

Ibrahim E. Abdalla

Jubail University College, Mechanical Engineering Department, P. O. Box 10074, Jubail Industrial City 31961, Saudi Arabia

ARTICLE INFO

Keywords:
Diesel
Biodiesel
Blended fuels
Thermo-physiochemical properties
FTIR spectra
CIE thermal and emission performance

ABSTRACT

An experimental work was conducted to obtain an insight on the variation of fundamental thermo-physiochemical properties for a range of mixtures of red Diesel (referred to here as D100), and Biodiesel (referred to here as B100) and the performance of such blends in a Compression Ignition Engine (CIE). The results for some specific properties such as density and viscosity; water content, pour and cloud points for D100, B100 and blended fuels (referred to here as B10–B90, the numbers indicate the percentage of Biodiesel in the blend), strongly indicate that the resultant mixture is an ideal solution and display a linear increase with increasing the B100 percentage in the blend. The cetane number showed a linear variation between B10-B80 but high value for B90 and B100. Sulphur content decreases continuously with increasing the Biodiesel percentages in the blend while the acid content increases with increasing B100 ratio. All these results carries no controversial issues with previous related studies.

The FTIR data obtained using gas analyser has shown that D100, B100 and fuels blends include a range of sub-hydrocarbons with Alkanes ($=C-$H) compounds as the main hydrocarbon. All Biodiesel blends has shown significant existence of Aldehydes ($-C=O$) and Ketones ($-C=Ost$). Nitro-compounds ($-NO^2$) exist in almost all fuels while Alcohols, ethers, acids and esters ($-C-O-$) are mainly associated with B100 and its blends. Allowing more time for B100 and its blends, the FTIR data strongly indicate that chemical composition changes and water contents increases in B100 and its blends leading to instability issues.

Using D100, B100 and 3 blends, mainly B25, B50 and B75 in a Diesel (CIE), the results showed that D100 releases higher rate of energy as expected compared to B100 and its blends. However the results showed that the blends burn more efficiently in the CIE used with the blend B75 producing the best engine efficiency and reasonably low fuel consumption. The emission data showed that the B100 and its blends produce less unburned hydrocarbon, CO,CO_2 and NO_x emission compared to D100. The better thermal and emission performance of the blends is most likely due to their balanced chemical composition as revealed by the FTIR spectra. The current work also indicates that blended fuels with higher ratio of B100 are recommended to use in CIEs to ensure efficient combustion.

1. Introduction

Liquid fuels extracted from crude petroleum or produced from renewable sources are predicted to remain the main sources of energy for long time to come. Although energy sectors worldwide is pursuing other renewable energy sources such as solar, wind, …, etc, the rate of energy generation from such sources has so far provided only a small ratio of the world energy, mainly in the developed world. In addition, as it stands now and in the near future, the cost of energy production from renewable sources such as wind and solar, is much more than the energy produced from burning liquid fuels (Valentina [1], Krozer [2]) extracted from crude petroleum. Further, in sectors such as the transport sector it is difficult to utilise renewables as a mean of providing the necessary energy. As a matter of facts, liquid fuels would remain the only option available. Worth to mention that although the prices of such fuels dropped during the last couple of years, geo-political circumstances might change at any time leading to higher prices of crude petroleum.

One of the downside of burning conventional fuels is the high rate of emission of greenhouse gases (GHG) including Carbon Oxides, CO_x, Nitrogen Oxides, NO_x and unburned hydrocarbon.The statistics in the UK shows that the transport sector, which is the majour consumer of

E-mail address: abdallai@ucj.edu.sa.

http://dx.doi.org/10.1016/j.fuel.2017.10.064
Received 9 February 2017; Received in revised form 10 October 2017; Accepted 12 October 2017

liquid fuels, account for 15% of UK GHG emission with Diesel engines accounting for close to 10% [3].

Liquid fuels produced from vegetables or animal fat sources are considered as renewable taking into consideration the fact that the plants from which they originate absorb most if not all of CO_2 emitted as a result of burning them (Nigam and Singh [4]. On top of being classified as renewables, their use in most of the existing combustion infrastructure has proved that they are able to reduce harmful emission associated with petroleum liquid fuels. Under the UK Renewable Transport Fuel Obligation (RTFO), the oil industry is supposed to add Biofuels to road conventional fuels of 3.5% in 2010/11, 4% in 2011/12, 4.5% in 2012/13 and 5% in 2013/14. Mixing liquid Biofuels with conventional fuels such as Diesel produces what is termed “blended fuels” or blends as referred to in this manuscript.

The thermo-physiochemical properties of such blends is expected to vary according to the feed stock from which the Biofuel is been produced and the percentage of the Biofuel in the blend. In order to understand the performance of any fuel in a specific combustion infrastructure, it is essential to establish such properties and understand the way they influence the combustion process. A typical example of two hydrocarbons is shown in Fig. 1 where Fig. 1(a) is methyl Decanoate ($C_{11}H_{22}O_2$)), a Biofuel and the closest conventional hydrocarbon to it is Decane ($C_{10}H_{22}$), shown in Fig. 1(b). It is apparent that the fundamental difference between the two hydrocarbons is the existence of two Oxygen atoms in the methyl Decanoate which in turn, influence the bonding of Hydrogen to Carbon atoms. Therefore, it is expected that the way these hydrocarbons react and burn in a stream of air will differ.

There is some evidence that Biofuels produce less emission of GHG compared to conventional fuels when burned under specific controlled environment although this fact/statement is debatable. This fact was stated in an abundance of research papers when Biofuels replaces conventional petroleum fuels in Internal Combustion Engines (ICEs) or other types of burners. Nevertheless, and based on recent review paper by Xue et al. [5] shown in Table 1 and more recent reviews in the field, considerable experimental work in CIEs contradict this statement. This poses a question regarding the mechanisms behind this important point and how to capitalise on it in order to reduce emission from burning Biofuels and their blends in different platforms. The in-depth reason why Biofuels produce less emission compared to conventional fuels is not fully explained so far and a subject of an ongoing debate between engineers and chemistry experts. There are some broad-meaning statements in the literature that attribute the decrease in emission from Biofuels combustion compared to conventional ones to the existence of an Oxygen atom(s) in the chemical structure of Biofuels. Presumably this is the reason, one would conclude that it is down to the way this Oxygen atom(s) influence the reactions path and rate, or, in other words, “they play a catalytic role” in influencing the combustion process.

Table 1
Statistics of effects of pure B100 on engine performances and emissions (Xue et al. [5]).

Variable	Total No. of References	Increase	Similar	Decrease
Power performance	27	2	6	19
Economy performance	62	54	2	6
PM emission	73	7	2	64
NO_x emission	69	45	4	20
CO emission	66	7	2	57
HC emission	57	3	3	51
CO_2 emission	13	6	2	5
Aromatic compounds	13	–	2	11
Carbonyl compounds	10	8	–	2

Taking the arguments in the paragraphs above into consideration, this experimental work aims to initially establish some fundamental thermo-physiochemical properties of a range of vegetable-based Biodiesel (B100) and its blends through mixing it with red Diesel (D100) with incremental percentage of 10% (B10–B90). The study also aims to obtain fundamental engine performance based on the conventional, Biodiesel and samples of the blends to shed light on the effect of thermophysical properties and chemical composition of these fuels on CIE thermal and emission performance. Establishing the right B100–D100 ratio that produce the best thermal performance and/or reduces emission is also one of the objectives of this work.

The rest of this manuscript is structured in the following manner. Brief literature review is presented in Section 2. Description of the experimental procedures are presented in Section 3. In Section 4 the experimental results done on fuels properties will be discussed while Section 5 discuss the results of the CIE and complement the performance of the fuels used. This is followed by the conclusion of the work.

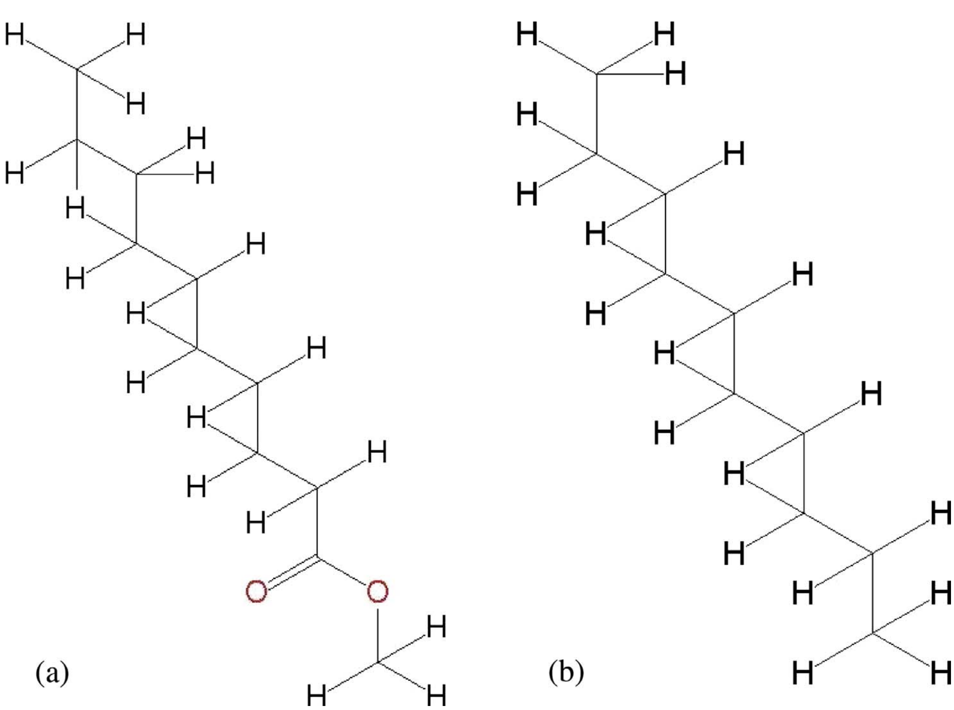

Fig. 1. chemical structure for (a) Methyl Decanoate and (b) Decane.