Renewable Energy 35 (2010) 368–378

Contents lists available at ScienceDirect

Renewable Energy

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

Comprehensive study of biodiesel fuel for HSDI engines in conventional and low temperature combustion conditions

Bernardo Tormos*, Ricardo Novella, Antonio García, Kevin Gargar

CMT-Motores Térmicos, Universidad Politécnica de Valencia, Valencia, ES, Campus de Vera, s/n, Edificio 6D. Camino de Vera s/n, 46022 Valencia, España

ARTICLE INFO

Article history:
Received 5 January 2009
Accepted 1 July 2009
Available online 28 July 2009

Keywords:
Diesel combustion
LTC
Biodiesel fuel
Future engines

ABSTRACT

In this research, an experimental investigation has been performed to give insight into the potential of biodiesel as an alternative fuel for High Speed Direct Injection (HSDI) diesel engines. The scope of this work has been broadened by comparing the combustion characteristics of diesel and biodiesel fuels in a wide range of engine loads and EGR conditions, including the high EGR rates expected for future diesel engines operating in the low temperature combustion (LTC) regime.

The experimental work has been carried out in a single-cylinder engine running alternatively with diesel and biodiesel fuels. Conventional diesel fuel and neat biodiesel have been compared in terms of their combustion performance through a new methodology designed for isolating the actual effects of each fuel on diesel combustion, aside from their intrinsic differences in chemical composition.

The analysis of the results has been sequentially divided into two progressive and complementary steps. Initially, the overall combustion performance of each fuel has been critically evaluated based on a set of parameters used as tracers of the combustion quality, such as the combustion duration or the indicated efficiency. With the knowledge obtained from this previous overview, the analysis focuses on the detailed influence of biodiesel on the different diesel combustion stages known ignition delay, premixed combustion and mixing controlled combustion, considering also the impact on CO and UHC pollutant emissions.

The results of this research explain why the biodiesel fuel accelerates the diesel combustion process in all engine loads and EGR rates, even in those corresponding with LTC conditions, increasing its possibilities as alternative fuel for future DI diesel engines.

© 2009 Elsevier Ltd. All rights reserved.

1. Introduction

In the last years, the overall concern about the global warming problem has changed the perception of emissions coming from internal combustion engines. As a result, the research effort in this field is being progressively focused on the control of the CO_2 produced by the combustion processes inside these engines because of its critical impact on the greenhouse effect. In this new research framework, several studies have shown how vegetable oils are alternative fuels for diesel engines due to their interesting potential for CO_2 emissions control [1,2]. However, the direct utilization of vegetable oils into diesel engines presents important difficulties due to its low temperature flow properties [3], but this important drawback has been overcome converting these oils in esters by a transesterification process [4], which reduces their viscosities and densities until values close to those usually observed for conventional diesel fuels [5]. These esters share the common name of biodiesel and they are also renewable, non-toxic and biodegradable [6], but its heating value is lower than that of diesel fuel [7]. Additionally, as biodiesel is obtained basically from vegetables or used fried oils, it is expected to become even more attractive because of the progressive fossil fuel exhaustion, playing an important role to promote a future Europe fossil fuel independence.

Recently, a lot of literature regarding the combustion and emissions using blends of diesel and biodiesel in different proportions in diesel engines has been published. However, due to the diversity of biodiesel fuels and the lack of a well defined methodology for comparing fuels with different physical and chemical properties, most of the research studies have been limited to the evaluation of the effective power and torque output, fuel consumption and engine-out emissions like monoxide of carbon (CO), unburned hydrocarbons (UHC), oxides of nitrogen (NO_x) and soot in multi-cylinder engines, without considering the biodiesel combustion characteristics [8].

* Corresponding author. Tel.: +34 963 877 650; fax: +34 963 877 659.
E-mail address: betormos@mot.upv.es (B. Tormos).

0960-1481/$ – see front matter © 2009 Elsevier Ltd. All rights reserved.
doi:10.1016/j.renene.2009.07.001

Definitions, acronyms, abbreviations

Latins

A	Geometrical area relative to the nozzle orifices.
ACT	Apparent Combustion Time
B100	Neat biodiesel
BTDC	Before Top Dead Centre
C	Constant
c	Fuel concentration
CA	Crank Angle
d	Diameter
E	Energy release
EGR	Exhaust Gas Recirculation
EOC	End Of combustion
EOI	End Of Injection
FL	Flame Length
Hc	Low heating value
HRL	Heat Release Law
RoHR	Rate of Heat Release
HSDI	High Speed Direct Injection
ID	Ignition Delay
M	Main injection
m	Mass of fuel injected
max	Relative to maximum
P	Pilot injection
P	Pressure
PC	Premixed Combustion
PCM	Premixed Combustion Mean
SOC	Start Of Combustion
SOI	Start Of Injection
ST	Stoichiometric
T	Temperature
TDC	Top Dead Centre
t	Time
u	Velocity
UHC	Unburned hydrocarbons
x	Jet length
Y	Mass Fraction

Greeks

α	Electrical SOI
Δ	Difference between injection pressure and back pressure.
ρ	Density
τ	Rate

Subscripts

D	Discharge
eq	Equivalent
f	Relative to fuel.
o	Initial/Nominal.
atm	Relative to atmospheric.

In terms of engine pollutant emissions results, there exists a general agreement and it is confirmed that biodiesel produces a systematic reduction in CO, UHC and soot emissions compared to conventional diesel fuel, which is directly related to its oxygen content [9,10]. However, the NO_x emissions increment observed for biodiesel has not been completely explained yet [11], but these emissions can be easily controlled introducing low to moderate EGR rates as it is usual in current diesel engines [12,13].

Other investigations have introduced some degree of combustion analysis to shed light on how biodiesel affects the combustion process and its relation with exhaust emissions, investigating the impact in the evolution of the Heat Release Law (HRL) and also in some parameters obtained directly from the HRL, mainly the ignition delay and the combustion duration.

Following this methodology, it is suggested that the higher NO_x emissions observed for biodiesel are mainly caused by the earlier start of combustion due to its slightly shorter hydraulic delay and also autoignition delay [14]. This slightly advanced combustion process for biodiesel is also supposed to explain the lower CO and HC emissions and even the reduction in soot formation. However, a recent research on biodiesel diffusion flame characteristics performed with optical techniques have related part of the NO_x increment with biodiesel to the reduced soot radiation heat transfer, which results in higher flame temperatures [15].

The suitability of biodiesel for low temperature combustion conditions has been also evaluated, confirming how a highly premixed combustion can be attained with biodiesel at low and medium engine load if the EGR level is increased over a given value [16,17]. In these conditions, a very low NO_x and soot exhaust emissions comparable with the levels attained with conventional diesel fuel has been attained.

Despite their obvious benefits, the use of biodiesel as alternative fuel in diesel engines for long periods of operation still presents some challenges mainly related to the durability of injection systems and lubricating oils and more research is required in these aspects [18].

From the previous biodiesel related literature review, the emissions and performance results using this fuel in multi-cylinder diesel operating with unmodified settings and with low or medium EGR ratios is well documented, but the fundamental combustion aspects below these results are not completely addressed yet.

Thus, the main objective of this research is the analysis of the influence of biodiesel on combustion characteristics in conventional and also in low temperature combustion operating conditions. This objective can only be attained comparing neat biodiesel and diesel fuels over a wide range of engine loads and dilutions of fresh air with exhaust gases in order to have a broad overview of the potential of biodiesel as a current and also future alternative fuel for diesel engines.

Nevertheless, the physical and chemical properties of biodiesel are different from those of diesel fuel, including a lower heating value and a higher stoichiometric fuel/air ratio. Consequently, the use of standard engine parameters to quantify load and dilution of fresh air with exhaust gases are not suitable to perform a rigorous comparison. This justifies the second objective of this research, which is the development of a methodology for comparing different fuels considering that this comparison should be based on physical parameters and independent from the type of fuel so as to allow generate equivalent operating conditions for any engine load and EGR dilution level.

2. Material and methods

This methodology is based on experimental tests performed in a single-cylinder engine since this type of facility generates much more accurate data compared to multi-cylinder engines [19]. This improvement in the quality of the data is due to a wider and better control of the engine operating conditions during the tests.

Download English Version:

https://daneshyari.com/en/article/301883

Download Persian Version:

https://daneshyari.com/article/301883

Daneshyari.com