Fuel 185 (2016) 743–762

Contents lists available at ScienceDirect

Fuel

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

Full Length Article

Performance and pollutant emissions from transient operation of a common rail diesel engine fueled with different biodiesel fuels

María D. Cárdenas [a], Octavio Armas [a,*], Carmen Mata [b], Felipe Soto [c]

[a] Universidad de Castilla-La Mancha, Escuela de Ingeniería Industrial, Edif. Sabatini, Av. Carlos III, s/n, 45071 Toledo, Spain
[b] Universidad de Castilla-La Mancha, Escuela de Ingeniería Minera e Industrial de Almadén, Plaza Manuel Meca, 1, 13400 Almadén, Spain
[c] Universidade Federal de São João del-Rei, Praça Frei Orlando, 170, Centro, São João del-Rei, Minas Gerais CEP: 36307-352, Brazil

HIGHLIGHTS

- Diesel pollutant emissions produced under transient operation have been studied.
- FAME fuels produced lower smoke opacity and higher NOx, CO and THC emissions under NEDC.
- Effect of FAME fuels on emissions clearly depends on vehicle tuning.
- Response of the electronic control unit is affected by fuel properties.
- FAME fuels have potential for reducing emissions if ECU tuning is adapted to fuel.

ARTICLE INFO

Article history:
Received 20 May 2016
Received in revised form 18 July 2016
Accepted 1 August 2016

Keywords:
Biodiesel fuels
Pollutant emissions
Engine performance
NEDC
Transient operation
ECU settings

ABSTRACT

Three fatty acid methyl ester fuels (from rapeseed, sunflower and soybean vegetable oils) and their blends (30% v/v) with diesel fuel were tested under New European Driving Cycle (NEDC) on an engine test bench. This allowed comparing engine pollutant emissions trends under transient operation. FAME fuels and their blends produced higher specifics emissions of nitrogen oxides (NOx), total hydrocarbons (THC) and carbon monoxide (CO) and lower smoke opacity in comparison with EN 590 reference fuel. The most important reason for obtaining these results was the impact of fuel properties on the electronic control unit (ECU) response, which was tuned for diesel fuel operation by the carmaker. This fact points out the potential of fatty acid methyl ester and its use, at high concentrations on road transport, for reducing greenhouse gases and pollutant emissions, by means of the optimization of electronic control unit settings when biodiesel fuel is used.

1. Introduction

Transport is a key sector of economy, employing directly around 10 million people, accounting for about 5% of gross domestic product (GDP) in European Union [1] and being the largest private contributor in R&D, with 41.5 billion euros invested per year [2].

However, transport must be environmentally sustainable and, although high efforts have been accomplished to reduce pollutant and greenhouse gas (GHG) emissions, air quality and climate change are still ones of the most critical concerns nowadays.

Regarding road transport, pollutant emissions (PM, NOx, THC and CO) have originally been regulated by Directive 70/220/EEC for light-duty vehicles [3] and amendments with the release of the consecutive Euro levels, which are more and more stringent. For complying this normative, the automotive sector has had to develop complex emissions control systems with a significant cost. It is shown [4] that Diesel light duty vehicles have increased its costs more than 30 times from Euro 1 to Euro 6 due to emissions control technology. This is a critical point for Diesel technology, mainly if it is compared to gasoline equivalent cost, which only has increased twice and in Euro 6 4 times lower than its Diesel equivalent emissions control technology cost. Other challenge for Diesel technology is the arisen issue related to the discrepancy between certification and real driving NOx emissions. This fact highlights the difficulties to control emissions under transient engine operation. Again, the problem with NOx emissions has not been observed with gasoline vehicles.

On the climate change side, transport is responsible for around quarter of EU greenhouse gas emissions. Particularly, only road transport contributes about one-fifth of the EU's total emissions

* Corresponding author.
E-mail addresses: mdcardenasa@gmail.com (M.D. Cárdenas), octavio.armas@uclm.es (O. Armas), mariacarmen.mata@uclm.es (C. Mata), felipesp@ufsj.edu.br (F. Soto).

http://dx.doi.org/10.1016/j.fuel.2016.08.002
0016-2361/

of carbon dioxide (CO_2), the main greenhouse gas. The EU has developed policies to reduce emissions derived from transport, such as CO_2 emissions targets for new passenger cars. In this issue, Diesel technology has an advantage in comparison with gasoline technology, due to its higher efficiency. However, new developments such as hybrid-gasoline could obtain nowadays lower CO_2 emissions than equivalent Diesel technology.

In this context, not only automotive sector has made many efforts to face environmental issues but also energy companies have reformulated fuels in order to match the fuel properties to emissions control systems or to reduce of engine out emissions [5]. Fuel Quality Directive (FQD) [6] sets important health and environment technical specifications for fuels to be used with Otto and Diesel engines and its last update mandates that fuel suppliers must reduce the GHG emissions of transport fuels by at least 6% in 2020, compared to a 2010 baseline, primarily by blending certified bio-derived components. Additionally, the Renewable Energy Directive [7] established that 10% of transport fuels on an energy basis must be derived from sustainably renewable sources by 2020. This percentage can include the use of bio-blending components, renewable electricity for vehicle recharging, biogas from waste materials, and other measures.

This European strategy is not only addressed by CO_2 emissions reduction commitment. Other factors such as improvement of energy security and domestic competitively by means of energy diversification play a key role in this topic.

Biofuels, particularly biodiesel fuels in diesel engines, are currently the most important type of alternative fuels, accounting for 4.7% of the total fuels consumed in EU transport in 2011. They can also contribute to a substantial reduction in overall CO_2 emissions if they are produced in a sustainable way.

The effect of biodiesel on emissions and performance has been addressed on a considerable number of publications and critical literature reviews [8]. However, the most of these studies have been accomplished under steady-state conditions and on engine calibrated to use conventional diesel fuel. Transient conditions, which are key challenge in terms of emissions and drivability management on a simultaneously way [9], are far from steady-state conditions when both, diesel and biodiesel fuels, are used. This fact joined to that related to the potential to optimize the modern engine control when biodiesel at high concentrations is used, points out that more understanding is required to explore further matching between biodiesel and engine control under transient conditions.

Therefore, this is a critical context for conventional powertrain and, in particular, for Diesel passenger cars due to the fact that it has to reduce pollutant emissions (mainly, NOx and particles) without penalty in CO_2 emissions. Modern Diesel engines have to demonstrate that they could be one of the key pillars in the portfolio of low CO_2 technologies for delivering clean, economical and affordable transport for future generations. Biofuels, such as FAME, could contribute positively to CO_2 balance and pollutant emissions, where transient operation is increasingly relevant for both issues. For that reason, this study analyzes the effect of FAME and its blend (30% v/v FAME) on pollutant and CO_2 emissions under transient cycle. Moreover, this study goes one step further because it points out how the potential of biodiesel fuels can be increased if the engine is calibrated for these fuels. This work presents the relationship between fuel properties on engine operating parameters and, both, on engine emissions and performance.

2. Experimental installation

Fig. 1 shows a general scheme of the engine test bench and the experimental equipment used in this work.

A 4-cylinder 4-stroke turbocharged, intercooled, with common-rail injection system Diesel engine was employed as experimental unit. The engine, whose main specifications are listed in Table 1,

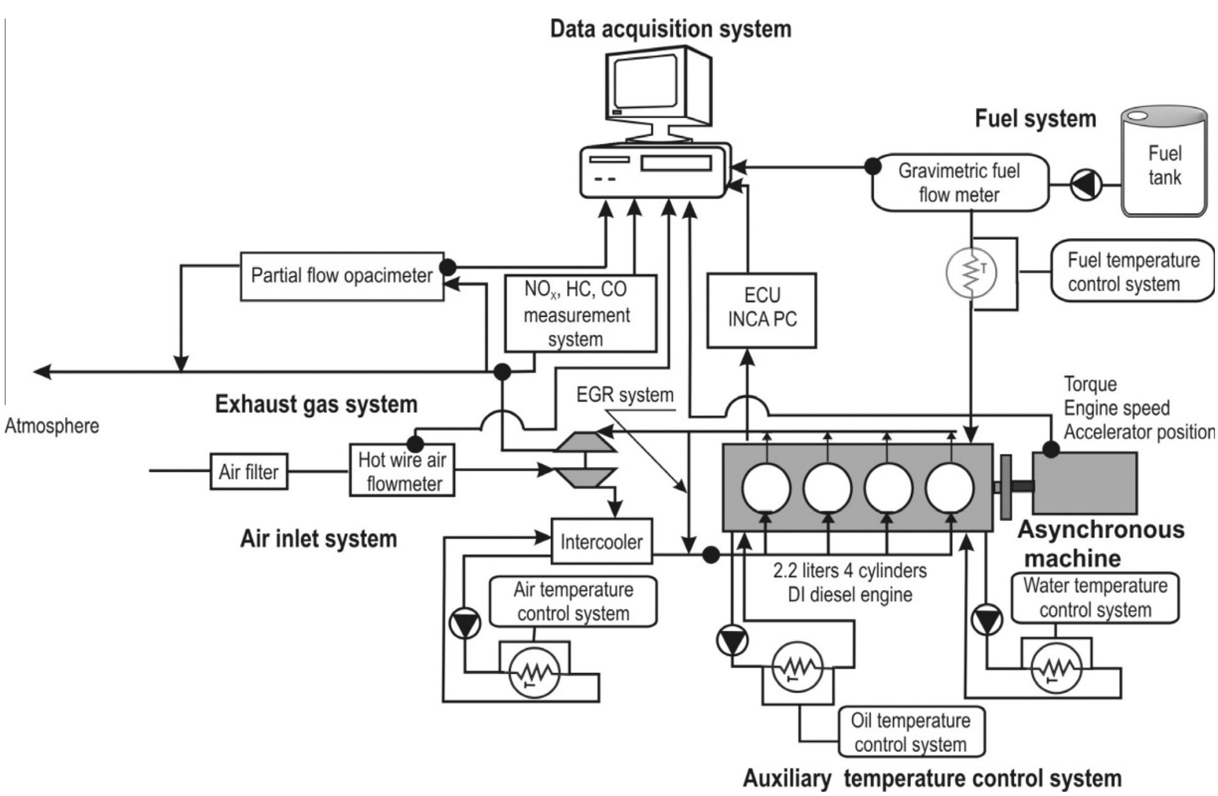

Fig. 1. Scheme of the experimental setup.