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Influence of biodiesel and diesel fuel blends on the injection rate under cold conditions

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HIGHLIGHTS

- The properties of biodiesel and biodiesel blends were tested in cold conditions.
- A kinematic viscosity correlation of fuel for cold conditions was developed.
- The influence of the percentage of biodiesel blend and temperature decreases on injection rate behavior was investigated.
- The discharge coefficients of biodiesel and biodiesel blends in cold conditions were investigated.

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ABSTRACT

During start-up of the engine under cold temperatures, conditions can be different when biodiesel is used due to the low fuel injection pressure and the high cloud point and high pour point. It is consequently of interest to understand the behavior of the injector under cold conditions when operating with biodiesel and the impact on the combustion process. This article presents an experimental study of the influence of diesel fuel and biodiesel blends on injection flow. A Bosch CRI 3.1 piezoelectric injector was used on a typical diesel engine. Five fuel types were tested: diesel fuel, winter diesel fuel, two diesel–biodiesel blends (B20, B50), and pure biodiesel (B100). Injection pressures were set at 30–60 MPa for the study of the injection flow characteristics at room temperature, in non-vaporizing conditions and in cold conditions. The experimental results show that cold temperatures (−5 and −8 °C) have no effect on the injection delay for any of the fuels. The discharge coefficients for all fuels are lower than at room temperature. When the fraction of biodiesel in the blend is increased, the change in the discharge coefficients is insignificant. New correlation coefficients for estimating the kinematic viscosity and the discharge coefficient has been presented for cold conditions.

1. Introduction

Biodiesel is a very interesting fuel because it is renewable, thus increasing energy security, it is environmentally friendly, and it has a higher cetane number and a lower sulfur and aromatic than pure Diesel. The main disadvantages of biodiesel are its higher viscosity, lower energy content, higher cloud point and pour point, higher nitrogen oxide (NOx) emissions, lower power and high cost [1]. However, many countries can produce their own biodiesel and blends with diesel fuel of 2–20% [2,3]. Governments (e.g. the European Union, the U.S.A.) have stipulated that fuel should be blended with biodiesel [3], although consumers are unconvinced about the use of biodiesel fuel blends in automotive engines because of their concerns about combustion efficiency, pollutant emissions and the impact on engine components. Attention has especially focused on pollutant emissions from biodiesel-fuelled vehicles with the implementation in 2014 of the Euro VI regulations.

The new standards involve problems related to cold-start, namely evaluation of post-treatment strategies and EGR at low temperature. The regulations concerning the quality of cold start at −7 °C will become increasingly stringent. At these temperatures the viscosity is higher. The blending of biodiesel with diesel fuel increases the cloud point, the cold filter plugging point (CFPP), or the pour point, which can clog the fuel lines and filters of the vehicle's fuel system [4]. Whatever the type of fuel, diesel–biodiesel

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Nomenclature

a	fuel sound velocity	PP	pour point
AR	degree of conicity (area reduction)	$p(t)$	dynamic pressure
Cd	discharge coefficient	ΔP	pressure difference
$CFPP$	cold filter plugging point	Re	Reynolds number
CP	cloud point	S_c	outlet geometric cross-sectional area
D_i	inlet diameter	SG	specific gravity at 15.5 °C
D_o	outlet diameter	S_{tube}	cross-sectional area of the measuring tube
$\dot{m}$	mass flow rate	V_{mean}	mean velocity at the outlet section
$\dot{m}_e$	estimated mass flow rate	T	fuel temperature
$\dot{m}_{measured}$	mean mass flow rate	$Troom$	room temperature
$\dot{m}_{th}$	theoretical mass flow rate	ν	fuel kinematic viscosity
$n_{orifice}$	number of orifices on the nozzle	ρ	fuel density
Pb	back-pressure		
Pi	injection pressure		

blends under 5% do not impact cold flow properties [5]. That is why it is important to know the behavior of the diesel injector in these conditions for different fuels.

Several publications [6-12] have highlighted the influence of fuel properties on the performance of the injector under standard temperature conditions. The increased viscosity decreases the flow rate in the nozzle slightly and favors the appearance of larger drops in the spray atomization. However, the decrease in the discharge coefficient is not observed with biodiesel mixtures, only with pure biodiesel [13,14]. On the other hand, the literature shows that it is not easy to find a relation between the fuel mass flow rate and temperature. It depends on the type of injector and type of fuel [15,16]. These two studies show that, in cold conditions, the discharge coefficient (Cd) decreases strongly when the viscosity increases [15]. Kegl [17] studied the impact of temperature on biodiesel for a specific configuration (a single injection assembly of inline fuel injection), and showed that when the temperature decreases, the injection duration, injection timing, mean injection rate and injection pressure increase. No information is available in the literature, however, on the injection rate of diesel–biodiesel blends under cold conditions.

In the present study, the chosen fuels were diesel fuel, biodiesel (rapeseed biodiesel), and diesel fuel blended with 20% and 50% rapeseed biodiesel. We also tested winter diesel which is doubly interesting in that it has the same kinematic viscosity as B20 and the same density as diesel. The fuel properties were measured at the operating temperature and at 8 °C, 0 °C, −5 °C, and −8 °C (very close to the CFPP of Biofuel). We investigated and distinguished the

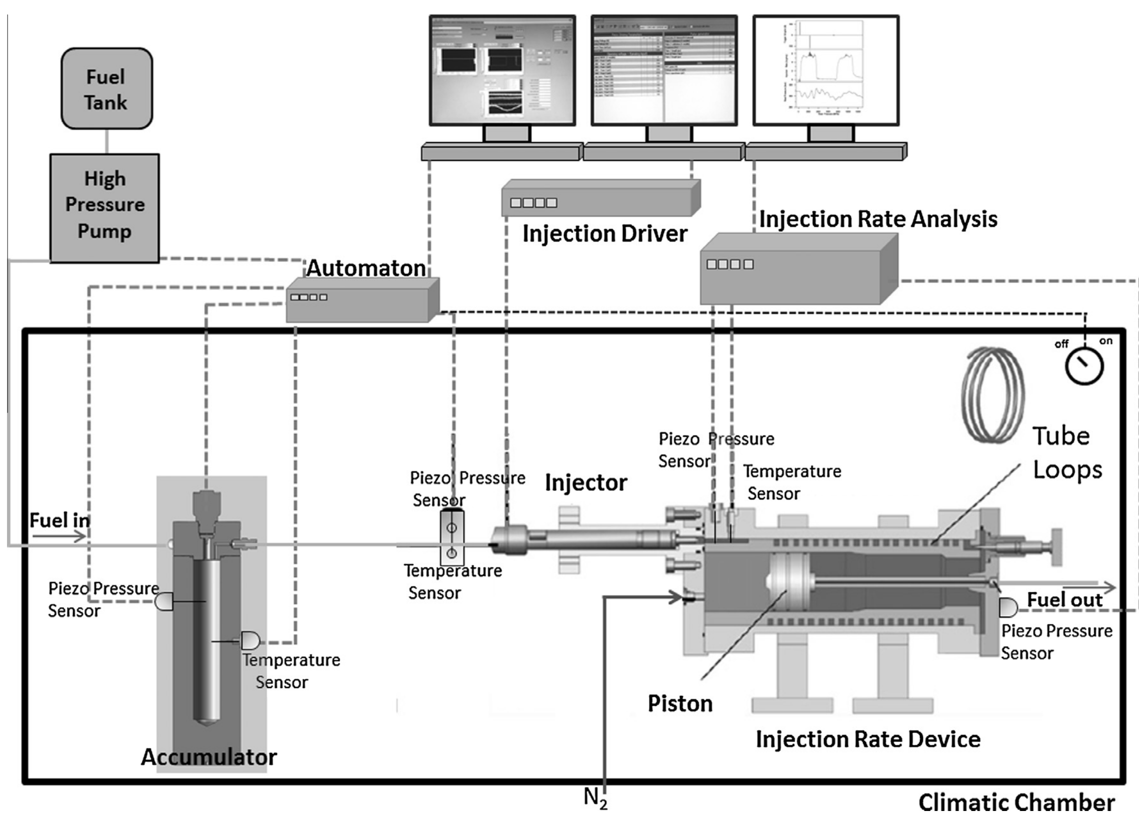

Fig. 1. Injection rate experimental setup (from IAV® technical specification) [10,14].