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Experimental study on the two stage injection of diesel and gasoline blends on a common rail injection system

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HIGHLIGHTS

- Two stage injection of diesel–gasoline blends on a common rail system is studied.
- Injection dynamics and characteristics are studied with changed parameters.
- Diesel/gasoline blends and diesel have similar cycle injection rate and quantity.
- Extended pilot injection pulse causes slightly reduced main injection mass.

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ABSTRACT

This paper characterizes the two stage injection processes of pure diesel and two diesel–gasoline blends using a diesel common rail injection system. The investigated fuel injection characteristics include the cycle injection quantity, injection rate and injector inlet pressure characteristics, with changes in gasoline proportion and pilot injection energizing pulse. Increased gasoline proportion has negligible influences on the cycle injection rate and mass, as well as the pressure dynamics during the injection process. In addition, the extended pilot injection energizing pulse leads to increased pressure drop at the injector inlet during the main injection and causes reduced main injection mass.

1. Introduction

The pursuit of high efficiency and clean internal combustion engines significantly promoted the development of novel engine combustion strategies. In the past two decades, novel combustion modes, e.g. premixed low temperature combustion (LTC) have been extensively studied, accomplishing simultaneous reduction in NOx and soot emissions with deteriorated thermal efficiency [1,2]. Fuel properties are crucial for the combustion process and emissions formation in the advanced engine combustion strategies [3,4]. The optimized fuel properties are proved to promote uniform mixture formation, which could restrict the in-cylinder soot-favorable region and avoid heavy usage of exhaust gas recirculation, as employed in the conventional LTC mode, to reduce combustion temperature below the soot formation threshold. The well-maintained combustion temperature could avoid the combustion deterioration as in the conventional LTC mode. Some researchers considered using blends of diesel and gasoline instead of diesel in advanced compression ignition (CI) engine combustion modes, and remarkable advantages in emissions control and fuel efficiency improvements were observed due to the extended ignition delay and improved in-cylinder fuel/air distribution [5–10]. Meanwhile, compared to gasoline LTC, using blends of diesel and gasoline does not cause combustion instability problems at low load and low speed conditions, as reported by Weall and Collings [11,12].

However, as blends of diesel and gasoline are proposed to the novel engine combustion strategies, except for their extended ignition delay, their changed physical properties may potentially affect the injection and spray characteristics, which are equally important for the mixture formation and engine combustion. Therefore, it behooves researchers to elucidate the injection and spray characteristics of diesel and gasoline blends. Some consensuses include that at non-reactive conditions, gasoline or diesel and gasoline blends produce similar spray tip penetration distances as diesel

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[13–15], and the spray droplet size decreases with increased gasoline proportion in diesel and gasoline blends [15,16]. Further, Payri et al. [13] revealed that gasoline produced lower mass flow rate than diesel with fully open needle valve, while Han et al. [15] found that diesel and gasoline blends with up to 40% gasoline volumetric proportion did not show significant differences in mass injection rate compared to pure diesel.

Some researchers also investigated effects of two-stage split-injection strategies on LTC engines fuelled with diesel and gasoline blends or gasoline-like fuels [17,18], because of the advantages of split-injection strategies in the combustion phase control and combustion noise reduction [19]. In the two-stage split-injection strategies, the pilot-main injection quantity ratio is a key factor influencing the mixture formation and heat release process. However, the main injection quantity is very sensitive to the instantaneous fuel pressure magnitude [20,21]. As diesel and gasoline blends are fuelled, the changed fuel physical properties may influence the fuel pressure propagation characteristics in the fuel pipe and common rail, thus impacting the main injection quantity. Therefore, this study aims to compare the two-stage injection processes of pure diesel and two diesel–gasoline blends on a high pressure common rail injection system. With changed pilot injection energizing times, the effects of gasoline proportion in fuel blends on the injection dynamics and the main injection quantities in the two-stage injection processes are illustrated.

2. Test method and test fuels

2.1. Experimental apparatus

The schematic of the fuel injection test bench is shown in Fig. 1, which includes a high-pressure common rail injection system, an electronic control unit (ECU) and a data acquisition system. The fuel supply, the rail pressure and the injection pulse profile were controlled by the ECU. Cycle fuel supply and instantaneous injection rate were measured by the mono injection qualifier. A current sensor was used to capture the injector energizing current, and a fuel pressure transducer was mounted at the injector inlet to monitor the fuel pressure trace. The data acquisition device was used to store the fuel injection rate, the energizing current and the inlet pressure of the injector. The model and specification of the main test apparatus are shown in Table 1. More information about the experimental apparatus could be referred to Ref. [22].

Table 1
Experimental apparatus.

Apparatus	Model	Specification
Common rail injection system		Rail pressure up to 140 MPa Rail volume: 30 cm^3
Injector	Multiple-hole injector	Hole number × diameter: 7 × 0.157 mm
Mono injection qualifier	EFS8246	Measurement range: 0–600 mm^3 Relative accuracy: 0.1%
Current sensor	Tektronix A622	Max input current: 100 A Output voltage: 10 mV A^{-1}, 100 mV A^{-1}
Fuel pressure transducer/amplifier	Kistler 4067A3000/4068	Measurement range: 0–300 MPa
Data acquisition	Yokogawa DL750	Sample frequency: 50,000 Hz

2.2. Test fuels and conditions

The test fuels in this study are pure diesel and gasoline–diesel blends named G0, G20 and G40, which represent that the gasoline volumetric percentages are 0%, 20% and 40%, respectively. The physical properties of test fuels are shown in Table 2. Gasoline has lower density, viscosity and surface tension than diesel, so with increased gasoline percentage, the fuel blends' density, viscosity and surface tension are reduced.

The experiment was carried out at the room temperature 298 K and atmospheric pressure 1 atm. The speed of fuel pump test bench was fixed at 600 rpm. Injection pressures were held at 40 MPa and 100 MPa, respectively. The pilot injection pulse widths were 0.3 ms, 0.5 ms and 0.8 ms and the injection intervals were 20 and 30CAD (Crank Angle Degree). During the experiment, the main injection timing was fixed on 3CAD BTDC (Before Top Dead Center). The injection interval was adjusted via changing the start of pilot injection. The data of 60 continuous injection cycles were collected in each operation condition. The cyclic coefficient of variation of fuel injection quantity was calculated by the equation as following:

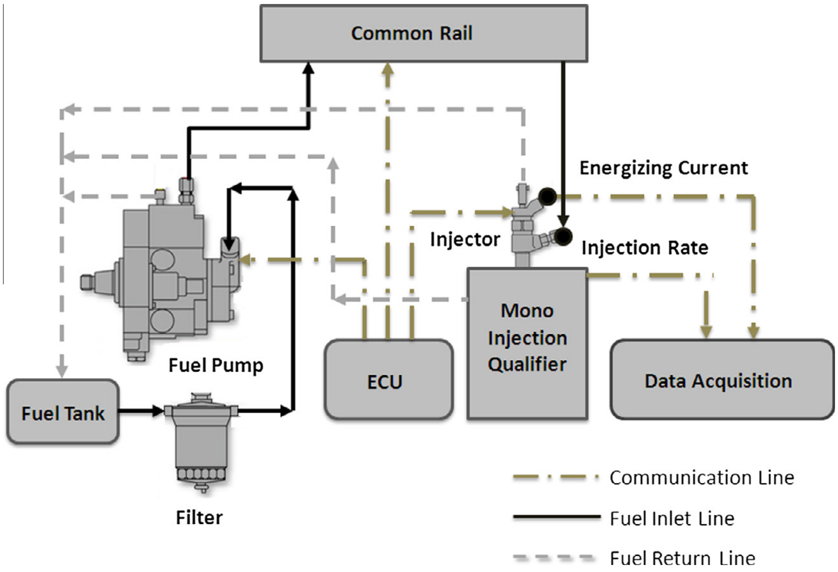

Fig. 1. Schematic of the fuel injection test system.