



# Experimental study of the two-stage injection process of fatty acid esters on a common rail injection system



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## HIGHLIGHTS

- Two-stage injection processes of three fatty acid esters (FAE) were investigated.
- The injector inlet pressure and fuel mass injected per cycle were studied.
- Fuel effects on the main injection masses are dependent on injection pressure.
- Methyl and ethyl oleates have higher speeds of sound at low injection pressure.
- The pressure wave of diesel propagates faster than FAE at high injection pressure.

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## ABSTRACT

The two-stage injection processes of three fatty acid esters, methyl laurate, methyl oleate and ethyl oleate, were investigated and compared with that of fossil diesel using a high-pressure diesel engine common rail injection system. The injection characteristics studied included injector inlet pressure characteristics, and rate and quantity of fuel mass injected per cycle. The effects of fuel properties and injection dwell time between the pilot and main injection events were also considered. Differences in the fuel properties of diesel and fatty acid esters caused modest changes in the main injection quantities and fuel pressure fluctuation characteristics after the end of injection, and the changes were affected by different injection pressures. The injection dwell time was also found to influence the injector inlet pressure characteristics at the start of the main injection event and thus the amount of fuel injected during main injection was slightly changed.

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## 1. Introduction

The limited fossil fuels reserves motivate engine researchers to seek clean and renewable alternative automotive fuels. Biodiesel, made from different renewable sources, is generally considered a potential sustainable alternative fuel for diesel engines [1,2]. In addition, biodiesel is found to have great benefits in reducing engine soot emissions [3,4], which is often ascribed to reduced pool burning and enhanced soot oxidation during combustion of biodiesel fuels [5].

Engine operation is a complex thermal-fluid-coupled process, which is sensitive to the changes in fuel properties. The physical

and chemical properties of biodiesel are quite different from fossil diesel, which can affect engine performance [6]. The accurate characterization and understanding of the changes caused by fuel properties variation are necessary for the control and optimization of biodiesel engine operation. One example is the biodiesel injection process [7,8], which directly influences the subsequent fuel/air mixing and in-cylinder combustion as well as fuel impingement on the combustion chamber and piston surfaces. Boehman et al. [9] found biodiesel could advance the injection timing in a mechanical injection system, which could partly account for the increased NO<sub>x</sub> emissions from biodiesel engines. Seykens et al. [10] established a one-dimensional hydraulic model to compare the single injection processes of diesel and rapeseed oil methyl ester (RME) on a common rail system. According to the modeling results, RME led to reduced volumetric injection rates as well as slower needle lift compared with fossil diesel, and the authors considered that the higher density of RME was the primary factor for the changes, while the difference in fuel viscosity only played a

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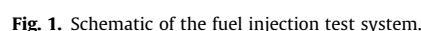
Moreover, modern engines are trending toward multiple fuel injection events as strategies to reduce emissions and improve engine performance [17]. Multiple fuel injection events increase the transient portion of the overall spray process. There are fewer experimental data characterizing the early portion of the spray time history for fossil diesel and biodiesel, and spray theory is less

The objective of this study was to determine the effects of different single component fatty acid esters on the performance of a two-stage injection strategy using a common rail injection system. The effects of the different properties of the fatty acid esters on the rate and quantity of fuel mass injected per cycle and the injector inlet pressure were measured as a function of injection dwell times between the pilot and main injection stages.

### 2.1. Experimental system

## 2.2. Test fuels

The fatty acid esters studied were methyl laurate (ML), methyl oleate (MO) and ethyl oleate (EO), and the two-stage injection characteristics were compared with those of fossil diesel (D) fuel. Some physical properties of test fuels are provided in Table 2. The data on the speed of sound and isentropic bulk modulus of diesel, methyl laurate and methyl oleate are from Tat and Van Gerpen [18], while the data for ethyl oleate are from Freitas et al. [19]. As seen in Table 2, the densities of the three fatty acid esters are marginally higher than the density of fossil diesel fuel, by less than



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