Mixture Formation and Combustion of Biodiesel Blended Fuels in a DI Diesel Engine

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Abstract

Mixture formation and combustion of biodiesel blended fuels in an optical accessible DI Diesel engine are studied. Optical experiments and a thermodynamic analysis have been performed on pure biodiesel, diesel and three mixtures. It is shown how spray formation and propagation as well as ignition delay and combustion are influenced by various properties of the different fuel mixtures.

Introduction

Biodiesel and its blends seem to be promising completions on a way to a modern energy mix in the traffic sector. Several groups have evaluated effects of biodiesel on exhaust gas emissions [1–5]. However not much is known about in-cylinder behaviour of such fuels. Apart from the higher cetane number of biodiesel some other crucial properties for spray formation and propagation, like viscosity and surface tension, considerably differ from those of diesel fuel. This has not only an impact when biodiesel as a pure fuel is used but also for all kinds of mixtures containing significant amounts of biodiesel. Therefore it is of interest to have a closer look on in-cylinder mixture formation and combustion of biodiesel blends in comparison to pure biodiesel and pure mineral diesel.

Experimental

This study was performed on pure RME biodiesel, diesel and three mixtures containing 25, 50, 75 volume percent biodiesel mixed with mineral diesel. Experiments were carried out in an optical accessible DI diesel engine. Mie scattering of fuel droplets was combined with a high-speed camera to observe the complete spray propagation and flame luminescence of individual cycles. Laser-induced fluorescence allowed a qualitative mapping of the distribution of evaporated fuel before start of combustion. OH-luminescence was detected with a UV-sensitive camera giving information about ignition spots and flame front propagation. The parameter variation of the experiments included variation of engine speed from 500 to 1000 rpm. The start of injection was varied from –12 °CA to +3 °CA and injection pressures were 600, 1000 and 1300 bar with two injection quantities. In addition to observation of mixture formation and combustion, a thermodynamic analysis of the pressure traces was performed leading to histories of heat release and burnt mass fraction.

Results and Discussion

The experiments showed that all fuels containing biodiesel have significantly higher penetration depths at smaller spray angles. It can be concluded that biodiesel causes poor spray disintegration with large droplets. This would lead to a retarded evaporation and therefore mixture formation with a higher physical ignition delay. The fuel blends with high concentrations of biodiesel (pure RME, 75%) show such high penetration depths that in the given engine spray-wall contact occurs (see Fig. 1). This leads to severe wetting of the piston bowl and a characteristic soot deposition.

These observations match the result of the thermodynamic analysis that showed reduced conversion rates for the fuels with high biodiesel content and longer ignition delays due to poor evaporation. Parameter variations revealed that biodiesel blended fuels benefit much more from increased injection pressure and hotter cylinder load. As an example this is illustrated in Fig. 2 where the increase in total heat release at higher engine speed and higher cylinder temperature becomes visible.

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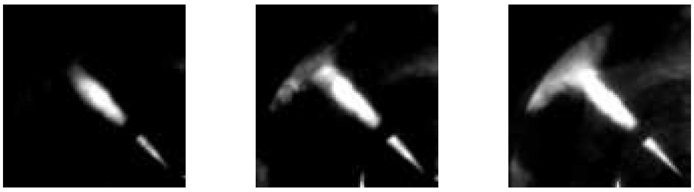

diesel **50% biodiesel** **biodiesel**

Figure 1. Spray-wall interaction observed by Mie scattering

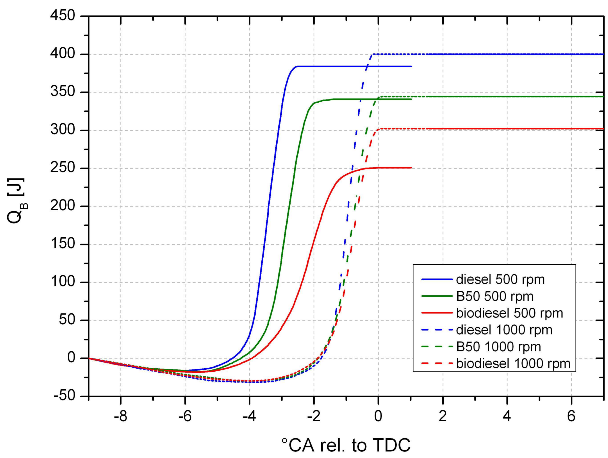

Figure 2. Heat release at 500 and 1000 rpm at a SOI of –9 °CA