Spray growth for diesel, synthetic, oxygenated and biofuels in an optical engine

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Introduction

Spray formation has been studied in an optically accessible heavy-duty diesel engine for a range of fuels: regular diesel, a Fischer-Tropsch synthetic fuel, pure Jatropha oil, Jatropha methyl ester (JME), rapeseed methyl ester (RME), tripropyleneglycolmonomethylether (TPGME, C10H22O4), model fuel idea (70% n-decane and 30% alpha-methyl-naphthalene) and Fischer-Tropsch fuel blended with either cyclohexanone or cyclohexane. Properties are listed in the table at right. Combustion related phenomena are studied as well and are presented on an accompanying poster [1]. Sprays are illuminated with an Ar+ laser and light scattering from the fuel sprays is recorded through the piston window with a digital high-speed CMOS camera (>31000 frames per second, >2000 images per cycle). Results from 2 out of the 8 nozzle sprays have been used in the data analysis.

Spray cone angle and penetration of the liquid phase are measured as a function of time. Both quantities are determined from the digital high speed movies by automated, custom made software algorithms.

Fuel

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Cn</th>
<th>Hu</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>regular diesel</td>
<td>0</td>
<td>827</td>
<td>96.2</td>
</tr>
<tr>
<td>TPGME + SMDS</td>
<td>9.49</td>
<td>818.3</td>
<td>74.8</td>
</tr>
<tr>
<td>cyclohexane + SMDS</td>
<td>9</td>
<td>864</td>
<td>-45</td>
</tr>
<tr>
<td>ideas-ME</td>
<td>0</td>
<td>817</td>
<td>35</td>
</tr>
<tr>
<td>Jatropha-oil</td>
<td>-10</td>
<td>919</td>
<td>36</td>
</tr>
<tr>
<td>tripropyleneglycolmonomethylether (C10H22O4)</td>
<td>-10</td>
<td>919</td>
<td>36</td>
</tr>
</tbody>
</table>

Engine, HS camera setup & movie

Introduction

Engine characteristics and experimental setup employing the high speed CMOS camera (12 bit dynamic range). The camera is synchronized to the crank shaft and records >200 images per cycle at 0.3° crank angle intervals with an exposure time of 24 microsec (0.2°(1 cycle).

Top Image: Image analysis is performed using the method described in Ref. 1 (to in this image are inserted “(mass%)” and a contour is determined at 80% of the spray shadow intensity.

Centre image (upper): the spray contour is determined by a threshold method

Centre image (lower): a macroscopic spray cone angle fcone is assigned based on the near-constancy of the local angle fcone/2 for a relatively large part of the spray (centre). Also shown is the triangular spray angle θ (similar to that in Ref. 1, θ is called the acute angle of a triangle which has an area A/2 and length f equal to those of the upstream half of the spray (centre), taking into account the invisible first part of length h. This makes out any spray cone irregularities and allows for an easier study of the temporal evolution of the spray angle.

Equilibrium spray liquid lengths (compare to experimental values obtained) modelled assuming that the steady liquid length are obtained using the model by Siebers based on the assumption of mixing-limited evaporation. Considerable effort was spent on collecting reliable physico-chemical properties for the fuels of interest. Both diesel and Fischer-Tropsch fuel are modelled as n-alkanes, which has proven to be a reasonable hypothesis for the liquid spray evaporation behaviour of diesel fuel. Jatropha oil is modelled as tricosenoic acid, which is one of its main constituents. Consistent with this, JME is modelled as methylpalmitate, properties of which are mainly available. RMD was modelled by the same substance, which is justified by the small variance in relevant fuel properties of methylsuberin and organic acids having approximately the same carbon chain length.

Using fluid properties as above, considerable differences in steady liquid lengths were found from the liquid length model. For pure Jatropha, the very small model values are unrealistic, since the mixing-limited assumption can no longer be expected to hold. For the other fuels, model values are in the same range as experimental values provided that an empirical constant in the Siebers model is replaced by the theoretical value. Moreover, the spray cone angle in the model had to be taken from literature correlations, since the liquid cone angle measured in the work does not cover the vapour phase and therefore gives rise to small values, leading to a severe overprediction of liquid lengths.

Modelling spray growth

Equilibrium spray liquid lengths (compare to experimental values obtained) modelled assuming that the steady liquid length are obtained using the model by Siebers based on the assumption of mixing-limited evaporation. Considerable effort was spent on collecting reliable physico-chemical properties for the fuels of interest. Both diesel and Fischer-Tropsch fuel are modelled as n-alkanes, which has proven to be a reasonable hypothesis for the liquid spray evaporation behaviour of diesel fuel. Jatropha oil is modelled as tricosenoic acid, which is one of its main constituents. Consistent with this, JME is modelled as methylpalmitate, properties of which are mainly available. RMD was modelled by the same substance, which is justified by the small variance in relevant fuel properties of methylsuberin and organic acids having approximately the same carbon chain length.

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Discussion & Conclusions

High speed digital imaging of the liquid fuel sprays in an optically accessible heavy-duty diesel engine, operating on a range of relevant fuels, has been used to determine the equilibrium lengths and cone angles of the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays. Variation in these two parameters is observed between fuels and as function of injection timing, rail pressure, heat release rate, gas density and angle of injection timing (§1). This may be explained by the fact that the fuel sprays.